BOOK OF
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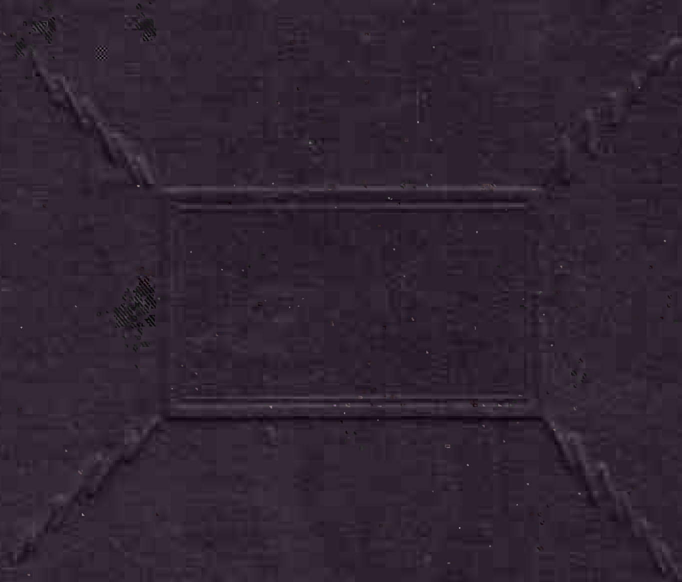

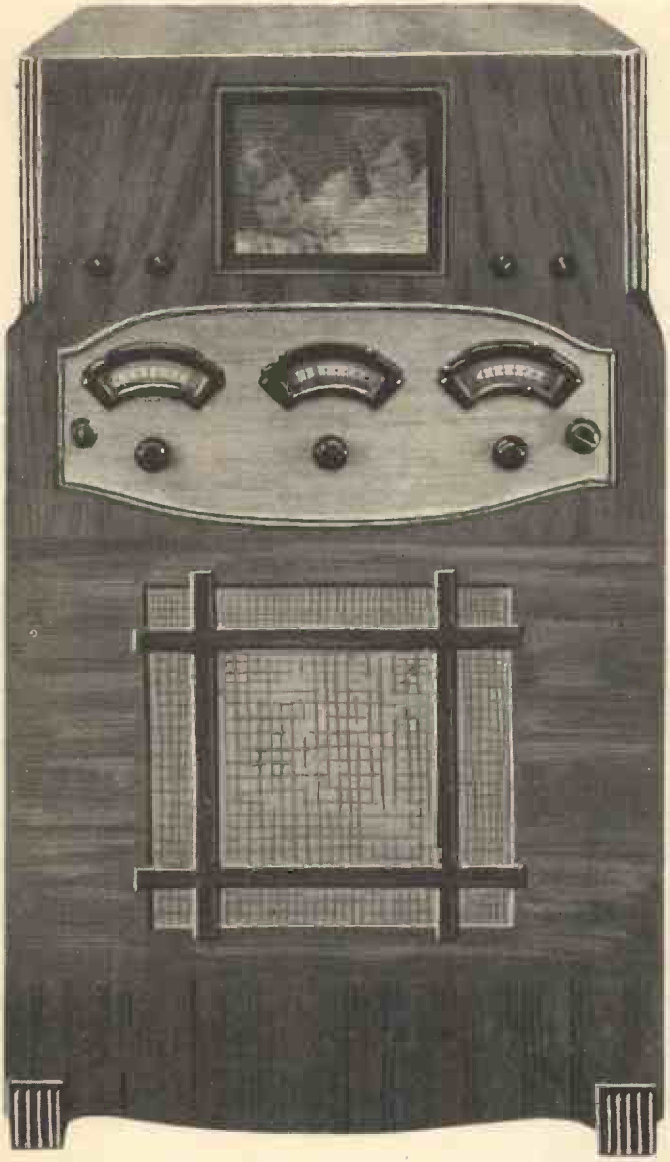

A FINE EXAMPLE OF MODERN HIGH DEFINITION TELEVISION SET DESIGN. THE CONSTRUCTION OF THIS OUTFIT IS FULLY DESCRIBED IN CHAPTER 19

Frontispiece

BOOK OF PRACTICAL TELEVISION

Edited by

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CONTENTS

PREFACE

Almost every minute of every day a new book begins to emerge from some press of some country in the world. Books about every conceivable subject, from stars and planets to terrestrial geology, and everything natural and artificial which lies between. It is true that there is an infinite number of things to write about, but it is equally a fact that most things are described in print to an infinite extent ! But there is one exception to this rule, and that is to be found in this fascinating subject of television. So quickly has television developed into a perfected and practical form out of a crude chrysalis, which rested apparently little changing through the years, that the scribes have yet to marshal their forces (and sources of information !) for the inevitable grand attack. Meanwhile, with television here at last and capable of bringing first-class talking pictures of both topical and purely entertainment natures into many homes, where can the seeker of facts and interesting information concerning it turn for a truly comprehensive and authoritative volume on the glamorous subject ? To be sure a few television books have been published, but the pioneering energy and enthusiasm of their authors could not invest them with the power to embrace the rapid march of television progress, for that branded their efforts as out-of-date almost before they were published.

Clearly, then, it is quite unnecessary to search for an excuse for the presentation of this present volume. In being an all-embracing work on modern television it has no predecessor. The " high definition " service and technique of the new television have been moulded into practical forms during only the few months preceding the writing of these words. It would have been humanly impossible for any one man to have gathered together all the material for the complete but popular television survey that lies between the two covers of this book. It was only possible with the aid of a carefully selected team of experts. Any practised technical journalist would be able to compile a passable handbook on say, electricity, for there is a wealth of appropriate text-books from which he could draw his information. But to make the " Book of Practical Television " the complete guide that it is, no such easy procedure was possible. A great proportion of the material had to be derived from first-hand experience, but this has enabled us to obtain a considerable amount of valuable information regarding the practical aspects of the science. For instance, the chapters describing the theory and operation of cathode-ray tubes and time bases not only deal with the most modern developments, but also give details of their relative performances. It should be mentioned that the pages devoted to apparatus suited mainly to low-definition systems are included not so much on account of the historical interest of the now terminated B.B.C. 30-line experimental transmissions, as because an understanding of the comparatively simple devices concerned proves an admirable introduction to the chapters covering the more complicated high-definition systems, and enables these more easily to be understood. Further, low definition technique will undoubtedly be practised for some long time by amateur transmitters and others interested in certain specialised aspects of television.

It will be noticed that the " Book of Practical Television " is a carefully welded amalgamation of the contributions of the individual experts and is not a disjointed series of articles. Its preparation was largely more in the nature of a collaboration, and many of the contributors actually gathered together on frequent occasions to discuss the work, even going so far as to carry out practical investigations and attend demonstrations together.

In view of the thoroughness of its compilation no doubt the " Book of Practical Television " will prove of great use to the television engineer and the television industry. But that is only incidental to its completeness. Its main purpose is to provide enjoyable and informative reading for the listener and potential " looker " and practical and trustworthy guidance for television experimenters and home constructors. That is why complicated formula and intricate geometrical illustrations of a purely theoretical interest have been avoided in favour of straightforward and easy-to-understand text and sketches and interesting photographs. Therefore, readers without scientific knowledge or training will not be handicapped ; we are confident that they will enjoy reading the book, and when they have done so they should have the satisfaction of knowing that they are equipped with as much general television knowledge as is at present practically the monopoly of a mere handful of men.

G. V. D.

Chapter 1

SEEING AT A DISTANCE

THE QUALITY OF THE NEW TELEVISION—THE FIRST B.B.C. STATION—HOW THE PICTURES COME OVER—BRIGHTNESS AND SIZE—CREATING PERFECT ILLUSIONS—CINEMA COMPARISONS—WHY AREN'T GIANT "CLOSE-UPS" CONSIDERED ABSURD?—TELEVISION DEFINITION A FIXED QUALITY—A "SILLY SYMPHONY" EXAMPLE—MENTAL ADAPTATION—EASY LOOKING—SHIFTING YOUR MENTAL VIEWPOINT—PERFECT HOME ENTERTAINMENT—PAVING THE WAY FOR MODERN STANDARDS.

So far, relatively few people have witnessed the modern television under domestic conditions. No doubt the generally accepted idea is that it is pretty crude and is little more than a tiny, dim flickering picture which is tiring to the eyes and doesn't show much more than shimmering spots and splotches. Probably many will decide to wait for "improvements," believing that everything must at its very beginning be only a ghostly precursor of better things to come.

This is a reasonable assumption in view of the crudenesses of the infant phonographs, motor-cars, aeroplanes and other innovations of the past generation or two. But history does not quite repeat itself in the case of television. The development of this new science has been without parallel. Television was "just round the corner" for many years. And it obstinately stayed just round the corner. Its progress seemed to halt in a most exasperating manner, and many reputable scientists came to the conclusion that twenty, or even fifty years at that, might not prove long enough for the final touches to be given to it.

Some went so far as to ask in so many words, "It is said that television is bound to come, but is *everything* bound to come? Didn't scientists search for centuries for the 'philosopher's stone' which could change base metal into gold? Aren't there men still convinced after scores of years of disappointment that the elixir of life, perpetual motion and other such things are almost within hand's grasp? Just round the corner, as it were?"

And then, practically overnight as it seemed, television turned the corner and arrived. For ten years or so it hovered on the doorstep leading from the laboratory to the public spaces of practical politics and then, with a single leap, it was over. The pessimistic prophets were shown to be false prophets.

Exactly how this all came about is a fascinating story, but before we venture on the enjoyable task of unfolding it for the benefit of readers of this book, it may be as well if we give a quick description of the new television. Incidentally, the reason why we shall continue to employ the terms, "new television" and "modern television" will become apparent to the reader before he reaches the end of this chapter.

The First B.B.C. Station. The first station of the B.B.C. television service is designed to serve London, and it will have a range of about twenty-five miles although, in certain cases, this range may be exceeded by as much as ten miles. Owing to the special nature of the television broadcasts it is not possible to extend this range appreciably merely by increasing the power of the transmitter, as can be done with sound broadcasting. Therefore, it will be necessary to have a chain of stations in order to provide a nation-wide service.

The pictures receivable in the home will vary considerably with the type of receiving apparatus used. That should be easily understandable. Any serviceable aeroplane will lift you into the air, but it depends upon the type (and price!) of the particular aeroplane you use as to how far and how fast it will carry you through the air. And so the brightness and size of your television pictures will depend upon the instrument you employ to glean movies from the ether. The definition of the pictures should not vary very much. As for flicker of the kind you get from a slowly-running cinema projector, the jerkiness that accompanied the early silent films, there will be very little of that whatever the receiving instrument.

The new television is transmitted with a "pictures per second" standard higher than the modern films. Therefore, its smoothness of action or picture movement, to use familiar if not quite technically correct words, is very good. The technical difficulties are greater than in the films, but by means of ingenious systems of interlaced scanning and so on, results fully comparable are obtainable. The definition, too, is largely a function of the transmission and not of reception. And it is "high definition" as all will know. That term means what it says. The detail of the pictures is comparable to the detail given by a good newspaper illustration, that is, on all but the poorest receiving apparatus.

Brightness and Size. The brightness and size of pictures is a purely reception limitation. On first rate gear black and white pictures bright enough to show clearly in a lighted room are possible on a screen twelve by nine inches, and even larger. Lower down the scale screens of but four or five inches or so square are met with and illumination making it desirable for the pictures to be witnessed in a dark room for comfortable " looking."

Nevertheless, the mistake should not be made of discounting entirely these smaller and dimmer pictures. It should be remembered that they are " talkies " and not silent pictures. There is a great difference between these, a difference that is psychological of course, but none the less real. It has been said that television can provide nothing more than a talking cabinet photograph. But size is not an all-important factor in the creation of illusion, though naturally it plays some part, and when it is controllable within wide limits as in a cinema, it is an art-quality that is employed generously. The question may well be asked that if a small television picture must inevitably militate against the creation of perfect illusion, why shouldn't a giant close-up on a cinema screen also do that?

Cinema Comparisons. In the course of any celluloid drama the glamorous features of one or more of the stars are reproduced in such dimensions that they practically fill the screen. But the audience is not at once aware of anything particularly incongruous in having the talking image of a giant face, perhaps forty feet in diameter, thrust before it, with cavernous mouth opening to reveal teeth truly as large as tombstones, and false eyelashes as big as cricket stumps waving with exaggerated emotion.

The fact is that the human imagination is immensely adaptable, and in those few words you have the answer to what many find to be an extremely perplexing problem, that is, if they ever think about this matter of film picture sizes at all; we would hazard the guess that very few do. There is a widespread belief that the bigger you make a picture the better it becomes. Certainly you will see more of the detail of a gnat's geography if you place him underneath a microscope, but the same reasoning does not apply to film pictures.

You can test this simply enough for yourself. Study a good postcard photograph of your favourite film star, or any clear photo for that matter, and then when you go to a cinema the next time carefully examine one of the huge close-ups which are flashed on the screen. The relative magnification will be something equal to that applied by a fairly high-powered microscope, but you won't see much, if any, exaggeration of detail. It is a good job too, otherwise the huge screen image would reveal such things as the sweat glands of the skin and other pathological details, which would in truth destroy many illusions!

Television Definition a Fixed Quality. If the cinema projector could be moved nearer and nearer to the screen the while you too moved closer in order to accommodate yourself to the smaller picture that resulted, you would find that the diminishing size was followed by an apparent increase in the sharpness of its definition, though you wouldn't see any more detail. This is a vital fact to note and the cause of it is that this definition as such is fixed by the film just as the definition of television is fixed in the transmission. No amount of juggling with screen sizes, etc., at the receiving end can add to the definition of the pictures.

It has also been said that while the compass of the ear is limited to a mere handful of different notes ranging from an organ's bass rumble to the squeak of a piccolo or violin top note, the compass of the eye can never be extended to its limits except by the broad open spaces of nature. And that any attempt to satisfy the eye with small pictures on a screen is bound to fail leaving the owner of that eye fully conscious all the time that he is in fact merely looking at a small picture. This may be right up to a point, and it depends upon the imaginative pliability of the looker as to how much he will be able to immerse himself in the subject of the picture and forget the vehicle which brings it before his eyes.

If it were impossible for any of us to become subjective lookers, cinematography would have had a short life limited to its novelty appeal. When this is remembered no conflict with the purely scientific optical laws, dealt with in the later chapters, need be suspected. We are here concerned with rather more abstract things—imagination for example. But the reality of the part imagination plays in the cinematographic art is considerable and is easily illustrated.

A " Silly Symphony " Example. It is common knowledge that the Mickey Mouse cartoons are nothing but clever drawings (about fifteen thousand of them to each episode) and yet such is the power of the human imagination that Mickey Mouse, Pluto, Donald the Duck and others of the ingenious Walt Disney creations have assumed almost human qualities in the minds of a large number of film fans. Some of the Silly Symphonies have been so successful in the creation of illusion that tears of emotion have been extracted from the eyes of audiences in sympathy with the plight of cartooned grasshoppers and other such fantasies. *Cartooned* grasshoppers, mark you, with no parallel in reality, grotesque sketches of grasshoppers as big as horses or as "small" as mice. Any screen personality or object is liable to shrink or expand at any moment and yet the audience remains quite enthralled. No jarring note of artificiality seems to be struck if the practised producer of a film decides to dodge about with his dimensions. On the contrary, with so much of it having been done, if a film presenting all its actors and actresses at a fixed distance from the camera's eye were shown, then no doubt the audience would consider that something was wrong!

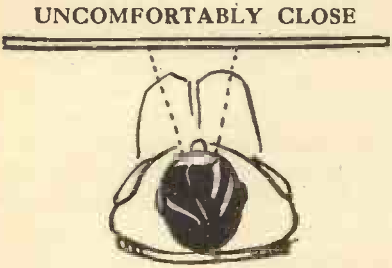

Fig. 1—In this case it is obvious that the screen is too large for a man sitting at that distance from it. He would find a smaller screen more satisfactory

The comparatively small television screen is, therefore, not in itself any insuperable limitation to the creation of illusion. It can only show talking human beings of doll-like size but the looker will not find himself feeling any sense of incongruity *so long as the subject is of good entertainment value.* If this were not the case then it could be as equally well argued that the receiving television screen should prove a better medium for Walt Disney's Silly Symphonies than the full size cinema screen, for his delightful insect and animal absurdities would for the most part appear in sizes nearer to the dimensions of the things cartooned.

Actually, however, it would seem that the size of the beings and things depicted is somewhat irrelevant and that the measurements of the screen are concerned almost entirely with clear seeing. You would at once notice the change if your favourite cinema suddenly introduced a quarter-size screen, for you would find it more difficult to see the pictures from the

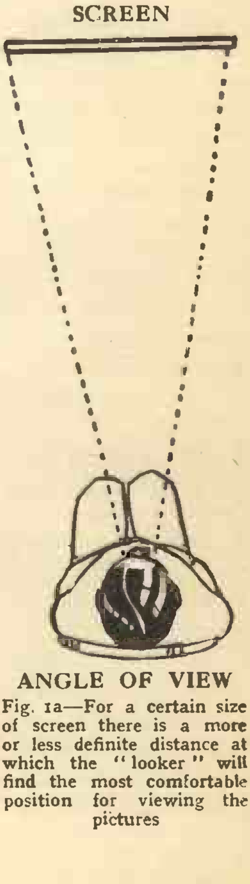

Fig. 1a—For a certain size of screen there is a more or less definite distance at which the "looker" will find the most comfortable position for viewing the pictures

position in the auditorium in which you usually sit. That is, if you possessed normal or short sight. Long-sighted folk might consider it an improvement, though in none of the cases might there be any real difficulty.

Mental Adaptation. Once more we come up against the psychological. A man occupying a seat from which he could obtain only a sharply oblique view of the screen is generally considered to be unfortunately positioned. And so he might be, unless he had occupied the same seat every time he went to the cinema for a long time because of some counter attraction such as a freedom from draughts. If those draughts were to be stopped, and he thereupon tried a central, and so-called " better " seat for which he would doubtless pay more money, he would probably find he was unable to obtain such " easy looking " for the simple reason that he had schooled his vision and his mind to the oblique view. Yet in another cinema he might enjoy a central view and not be conscious of any feeling of strangeness. " Easy looking " seems to be the clue to the whole problem. And our man in the side seat of the cinema found his easiest looking there because his hatred of draughts was greater than his desire for the more natural straight-on viewpoint.

Easy Looking. Would you get easy looking if your television screen were as big as the side of the room ? Decidedly not. You would be " too close to the picture." You would feel the urge to get farther and farther back so that you did not have to wave your head about from side to side and up and down continuously in order to be able to comprehend the whole of the picture and all that was taking part in it. These points are illustrated in Fig. 1 and Fig. 1a.

SUDDEN EXPANSION!

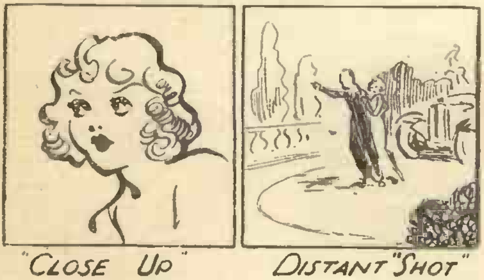

Fig. 2—" Any screen personality or object is liable to shrink or expand at any moment. . . " An example of the film producer's method of ensuring " easy looking "

A screen of six by eight inches can provide " easy looking " for as many people as would normally be present in a normal household to see what was coming over in the way of television. Going back again to the cinema we can now appreciate the reason why those gigantic close-ups do not strike a note of incongruity so long as the film drama has been scientifically produced. The heroine has, perhaps, received a shock or is undergoing the strain of some other emotional experience, a close-up of her face is obviously called for on the grounds of easy looking, so that, without strain, the audience can, as it were, peer right into her countenance in order to witness its changes of expression, to see the lips quivering, the tears starting to the eyes or the smile breaking (Fig. 2.).

On the legitimate stage there is no such completely satisfactory expedient, and so in that medium she has to make sure she is near the footlights and tilts her head to the added illumination of a carefully focused spotlight ! Even with all that it is dubious as to whether a galleryite would obtain as easy looking as can be obtained with the small television screen. It is very difficult to define hard and fast limits, but we would hazard the opinion that at a distance of ten feet, and most of us cannot get much farther away than that from anything in the room in which we listen and look-in at home, there is no advantage in having a screen larger than, say, four feet square and that a screen appreciably bigger might in fact militate against easy looking. With smaller screens you can go closer, but, on the other hand anything smaller than the six by eight inches may certainly cramp the illusion, for the detail of the pictures will crowd together and lose apparent clarity and you will become conscious that it is a small reproduction.

Shifting Your Mental Viewpoint. There is still the fact of smallness as such being able to create illusion to be explained This won't take long. The sizes of things are comparative. When you look overhead at an aeroplane flying in a clear and cloudless sky, you don't conclude that it is a toy aeroplane, although its apparent size is only a matter of inches. You know it is an object of some number of yards in length and width made to look small because it is a considerable distance away (Fig. 3).

"BRINGING IT NEARER"

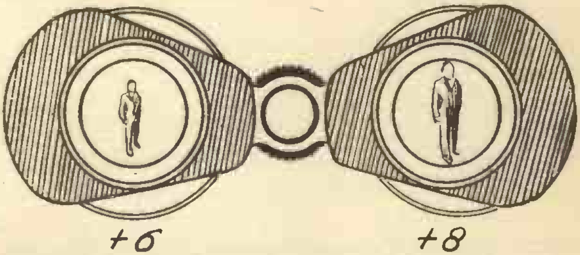

Fig. 3—The phrase "bringing it nearer," as applied to use of field-glasses is a practical example of adapting view points. The higher the magnification of the "glasses" the nearer you seem to be to a given distant view because of the increase in the size of the picture as you see it

Therefore, your tiny pictures of artistes on the television screen appear to you as real enough because mentally and subconsciously you have removed your viewpoint to some distance away from them, and you will find it helpful in maintaining the illusion if you look at the television pictures in a darkened room so that the familiar articles surrounding the receiver cannot be seen, and, therefore, do not provide dimension comparisions and locate the screen.

Perfect Home Entertainment. No, you do not need to stretch your imagination in order to derive entertainment from the modern television. Our case for it may or may not sound convincing to those who have not yet enjoyed an hour or two of looking. Those who have done so will agree that one of the better Silly Symphonies or a good straightforward talkie or an entertaining variety act is every bit as absorbing on the television screen as it is in a music hall or movie theatre. Perhaps rather more so, because there are quieter conditions. No deafening roars of laughter drowning parts of the dialogue, no coughing from all angles, no kicking at the back of the seat, but plenty of room to stretch your legs from a comfortable chair and a position relative to the screen which can be chosen to a nicety. In short, television in the home is the ideal and perfect medium of entertainment, and it remains in the hands of the B.B.C. to see that the substance is worthy of the medium!

Its limitations are much fewer than probably most people realise. Anything that you see on the screen at your local cinema can be reproduced on the television screen from the same kind of talking film, although with perhaps not quite the same amount of detail in the extended shots. Pretty nearly though, and it is not impossible for the present systems to be given the little extra refinements needed for cinema standard of definition to be achieved, although many would consider that the steps necessary would not be worth while in view of the present television standards.

Paving the Way for Modern Standards. The television that was broadcast for several years before the arrival of the new high definition type was pretty poor stuff from the entertainment point of view, and no one should attempt to base a judgment on television in general from any experience of those transmissions in particular. The only thing which can be said for them is that they paved the way for the new television in certain respects. In doing that, however, they served a valuable purpose.

The apparently sudden change came about because of the action taken by the Postmaster-General in 1934. It was as though he suddenly said to himself: " What is all this talk about a better, clearer television? Is it a fact that vastly superior results can be obtained than is given by the present experimental broadcasts? Is it possible that by taking certain drastic steps a service of high-class television might be possible? I must gather some experts together to inquire into this."

Anyway, the Government appointed a representative committee to investigate the television situation for him.

Chapter 2

TELEVISION ARRIVES

A PREDICTION THAT HAS COME TRUE—THE EARLY EXPERIMENTS OF JENKINS AND BAIRD—AN OFFICIAL COMMITTEE IS APPOINTED—IMMEDIATE TELEVISION SERVICE RECOMMENDED—THE ADVISORY COMMITTEE—COVERING THE COUNTRY—PATENT PROBLEMS—SPONSORED PROGRAMMES—" SELLING TIME " IN AMERICA—TELEVISION AND THE FILM INDUSTRY—VISION EXTENDED BEYOND ALL HORIZONS.

A mere twelve years ago television was a fantasy of the distant future to all except a very few indeed. Among these few was the editor of " Popular Wireless " who, in the very first issue of that journal (dated June 3rd, 1922), wrote, " The radio telephone has brought speech and music to our homes on the back of wireless waves. That alone is something to marvel at—the fact that we can hear a man singing to a piano accompaniment fifty or a hundred miles away.

" But what will the general public think when they instal apparatus which will enable them to *see* as well as hear by wireless ? To the novice in wireless work this suggestion must savour very much of black magic or the ravings of a second Munchausen and De Rougemont rolled into one. Jules Verne himself would have paused before suggesting such a possibility.

" Photographs have already been successfully transmitted by wireless, but the fascinating problem of transmitting living pictures by wireless is still in its undeveloped stages. Yet it is a possibility —a distinct possibility, amazing as it may seem. Inventors have already made crude attempts at the accomplishment of this great feat, and there is little doubt that a radio telephone vision will be an actual fact before very many years have passed us by."

And an extremely sound prediction as has now been proved. The more remarkable because television was so undeveloped in actual fact as to be to all intents and purposes practically non-existent. It had not gone beyond the laboratory stage of crude experiment in first principles.

The Early Experiments of Jenkins and Baird. A whole year passed before Jenkins in America demonstrated the television transmission of simple silhouettes. About six months after that Baird accomplished the television of a human face and, without detracting in any way from the importance of the step, it must be noted that the results were extremely crude. One saw a flickering pattern of dim light and shade which certainly held something of the shape of a human head, although the features were little but restlessly shimmering shadows. The illumination was about that of the dial of a luminous watch!

Subsequent to three further years of development, the Baird system was sufficiently advanced for the B.B.C. to extend facilities for experimental transmissions from a broadcasting station. Progress continued more rapidly after that—for a time. And then there was a slowing down in so far as the broadcast television was concerned, because it gradually became just as good as it could be, although its most enthusiastic supporters could not claim that its best results constituted anything much more than rather feeble entertainment value for the general public. Many considered that the time had come for the experimental transmissions to be discontinued, as they had served their purpose in giving television a trial, and that experience showed that it was not good enough to provide a proper broadcast service.

But there were many others to point out that these particular television broadcasts did not reveal the full possibilities. Not through any fault of the particular system used, but because the radio wavelengths employed formed a hard and fast barrier that impeded any further improvements. It was also said that given certain facilities very considerably superior pictures could be transmitted and received. That, in fact, real television was there to be enjoyed if only it were given a chance.

An Official Committee is Appointed. In May of 1934 the Government appointed an investigatory committee having the following terms of reference:

"To consider the development of Television and to advise the Postmaster-General on the relative merits of the several systems and on the conditions under which any public service of Television should be provided."

The chairman was Lord Selsdon, a former Postmaster-General; Sir John Cadman was the Vice-Chairman and, in view of his vast oil and other interests, was fully qualified to assess the commercial aspects of the new science. Col. A. S. Angwin, Assistant Engineer-in-Chief and Mr. F. W. Phillips, Assistant Secretary G.P.O., represented the Post Office on the Committee, and Vice-Admiral

Sir Charles Carpendale, Controller, and Mr. Noel Ashbridge, Chief Engineer B.B.C., constituted a powerful broadcasting contingent. There was also Mr. O. F. Brown of the Department of Scientific and Industrial Research.

A very well-balanced committee, neither so large as to be unwieldy, nor so small as to render it at all likely that if there were shortcomings or prejudices on the part of any one member he could sway the findings. We should hastily add that we have personally met most of these gentlemen and can state that a more clear-thinking, unbiased and fair-minded body of individuals would be extremely hard to find.

The committee worked on their task for seven months. They examined all the television systems belonging to concerns who were prepared to give demonstrations, and came to the conclusion that the most distinctive of those developed in this country were the Baird, Cossor, Marconi-E.M.I. and Scophony.

Delegations of members of the committee visited both Germany and the United States in order to investigate the television situation in those countries.

Immediate Television Service Recommended. The ultimate publication of their report came as something of a bombshell. It had been thought that the most that would be recommended was a careful extension of the existing experimental broadcasts but on lower wavelengths. Instead of that, however, the immediate organisation of a television service was suggested, and the committee went so far as to say that they considered it probable that the satisfactory reproduction of even outdoor scenes, such as lawn tennis matches, the finishes of horse races and processions, could be obtained.

In regard to the experimental transmissions the report stated :

" In the case of these transmissions the size of the elements (elementary areas) composing the picture is such as to admit of transmission being effected in a series of thirty lines per picture and each picture is repeated 12½ times per second (see paragraphs 12-15).

" Any pictures built up with a structure of the order of thirty lines are, however, comparatively coarse in texture. Little detail can be given, and generally speaking the pictures are only fitted for the presentation of ' close-ups '—e.g., the head and shoulders of a speaker—and the quality of reproduction leaves much to be desired. Moreover, any frequency of the order of 12½ pictures per second gives rise to a large amount of ' flicker.'

" Whilst low definition Television has been the path along which the infant steps of the art have naturally tended and, while this form of Television doubtless still affords scientific interest to wireless experimenters, and may even possess some entertainment value for a limited number of others, we are satisfied that a service of this type would fail to secure the sustained interest of the public generally. We do not, therefore, favour the adoption of any low definition system of Television for a regular public service." *

As is clearly explained in a later chapter in this book which deals with television wavelengths, these transmissions were arbitrarily limited to a low definition because of the wavelengths allotted to them. The definition of a television transmission decides the amount of room it occupies in the ether. No greater definition is possible on the ordinary wavelengths used for broadcasting or the transmission will tend to interfere with other stations.

The committee were of the opinion that a degree of definition equal to at least 240 lines per picture should be aimed at and that there should be a minimum picture frequency of 25 per second in order to minimise flicker. But to obtain this high result it was necessary to go down to ultra-short wavelengths, and these have a limited range of transmission. They cannot provide the hundreds of miles of range that is possible on the medium and long wavelengths.

But it was considered that a standard had been reached in practical televising on the very low wavelengths that justified the first steps being taken to establish a public television service of the high definition type in this country, though it was added that the low definition transmissions might be continued for a time as well, for the benefit of experimenters.

The Advisory Committee. In regard to the steps to be taken to establish the service the report said :

" Whilst we think that the British Broadcasting Corporation should exercise control of the actual operation of the television service to the same extent and subject to the same broad principles as in the case of sound broadcasting, we recommend that the initiation and early development of this service should be planned and guided by an Advisory Committee appointed by the Postmaster-General, on which the Post Office, the Department of Scientific and Industrial Research and the British Broadcasting Corporation should be represented, together with such other members as may be considered desirable. We recommend that this Committee should be appointed forthwith, for a period of, say, five years.

" The Committee should advise on the following :

" (a) The performance specification for the two sets of apparatus mentioned in paragraph 56, including acceptance tests, and the selection of the location of the first transmitting station.

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* The extracts from the Report of the Television Committee, which appear in this book, are published with the permission of the Controller of H.M. Stationery Office.

" (b) The number of stations to be built subsequently and the choice of districts in which they should be located (see paragraph 57.)

" (c) The minimum number of programme hours to be transmitted from each station.

" (d) The establishment of the essential technical data governing all television transmissions, such as the number of lines per picture, the number of pictures transmitted per second, and the nature of the synchronising signals.

" (e) The potentialities of new systems.

" (f) Proposals by the British Broadcasting Corporation with regard to the exact site of each station, and the general lines on which the stations should be designed.

" (g) All patent difficulties of a serious nature arising from the operation of the service in relation to both transmission and reception.

" (h) Any problem in connection with the television service which may from time to time be referred to it by His Majesty's Government or the British Broadcasting Corporation.

Here is an extract from paragraph 56 :

" There are two systems of high definition Television—owned by Baird Television Limited and Marconi-E.M.I. Television Company Limited respectively—which are in a relatively advanced stage of development, and have indeed been operated experimentally over wireless channels for some time past with satisfactory results. We recommend that the Baird Company be given an opportunity to supply the necessary apparatus for the operation of its system at the London station, and that the Marconi-E.M.I. Company be given a similar opportunity in respect of apparatus for the operation of its system also at that station."

It goes on to define certain conditions such as that the companies should agree to allow the introduction into their apparatus of other devices than those covered by their own patents if this should be recommended by the Advisory Committee, and that transmissions from both sets of apparatus should be receivable on the same type of set without much being needed in the way of adjustment or alteration.

In regard to programmes the following recommendations were made :

" It is scarcely within our province to make detailed recommendations on the subject of television programmes. To what extent those programmes should consist of direct transmissions of studio or outdoor scenes, or televised reproductions of films, must be determined largely by experience, technical progress and public support, as well as by financial considerations. No doubt the televising of sporting and other public events will have a wide appeal, and will add considerably to the attractiveness of the service. We regard such transmissions as a desirable part of a public television service, and it is essential that the British Broadcasting Corporation should have complete freedom for the televising of such scenes with appropriate sound accompaniment, at any time of the day.

"With regard to the duration of television programmes, we do not consider that it will be necessary at the outset to provide programmes for many hours a day. An hour's transmission in the morning or afternoon which will give facilities for trade demonstrations and, say, two hours in the evening, will probably suffice. As regards the future, the British Broadcasting Corporation and the Advisory Committee will doubtless be guided by experience and by financial considerations."

A commencement was to be made with the one London station, and a network of stations built up to cover the country subsequent to the experience gained with the first station. The cost of the London station up to the end of 1936 was estimated at £180,000. The pros and cons of the various ways in which this money could be found were argued at length, but ultimately it was suggested that it should come out of the existing 10s. radio licence revenue, though the way was left open for a future reconsideration of this particular question.

The Postmaster-General at once acted, the Advisory Committee was formed and work began on the practical organisation of the television service.

Covering the Country. It was a very formidable task and is not yet completed. As a matter of fact it has to be admitted that it may not reach conclusion for many years. It has been calculated that ten television stations will be able to serve fifty per cent of the population. Those ten stations may all be working within this present decade. But unless some new technique of transmission is developed, it is doubtful whether the remaining fifty per cent of the population will be served with television for some long time. For the complete coverage of the country probably fifty or more stations would be needed, and although the number may not prove prohibitive as the service expands, it would be foolish optimism to regard it as a possibility of the immediate future for financial if for no other reasons.

Ultra-short wave television stations cannot be linked up as easily as ordinary broadcasting transmitters. That is another problem that confronts the engineers of the B.B.C. and the Post Office. Just as the medium and long-wave bands in the ether are unable to accommodate high-definition television, so it is impossible to convey the electrical impulses of television along ordinary telephone cables. They can handle frequencies only up to ten thousand cycles or so to give a generous estimate, but the high-definition television employs frequencies of the order of a million or more.

Recently, special cables able to carry such frequencies have been developed. But they are comparatively costly. Alternatively, it has been suggested that it may prove practical to link television studios and transmitters by means of short-wave radio.

The establishment of any one television station, let alone that of a whole chain, is not without its special problems. The ultra-short waves do not " soak " an area as easily as the longer ones. Hills and high buildings tend to cast shadows. Therefore, it is desirable to situate the transmitter on as high a vantage point as possible, and to employ a high aerial.

Patent Problems. In addition to engineering problems there have been the problems of patents for the Advisory Committee to deal with. In this connection the Radio Manufacturers Association has been hard at work assisting to handle what is undoubtedly a matter fraught with difficulties. Certain firms have spent large sums in the development of television systems and they justifiably look forward to the reception of royalties or profits from the sale of receiving apparatus to the public as a return on their outlays.

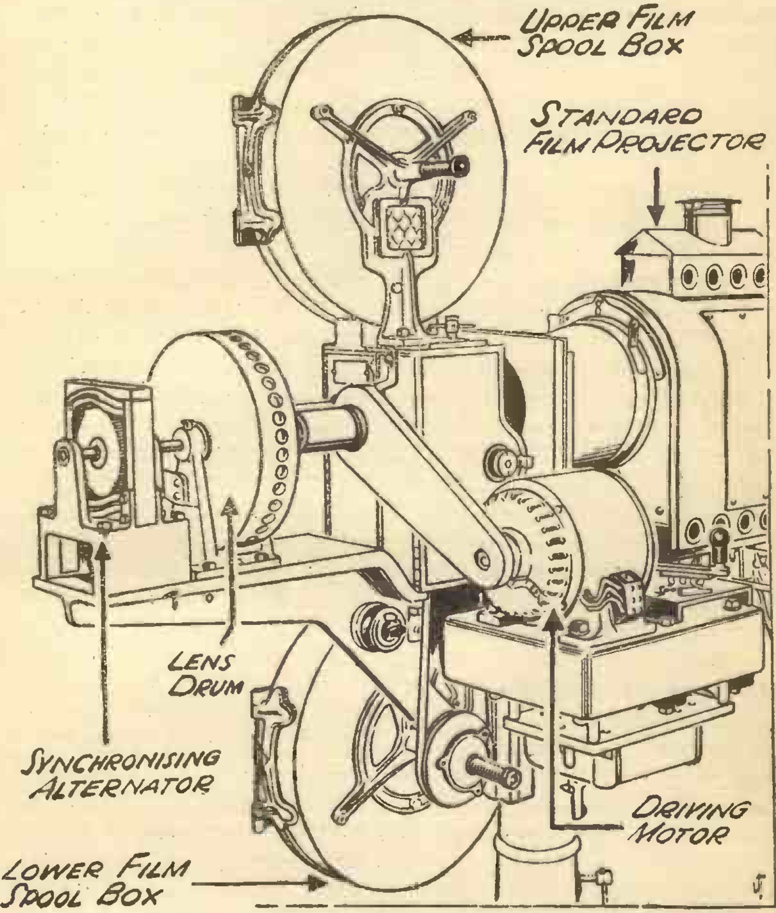
But there is the radio industry as a whole to consider, for monopolistic " corners " must be avoided, and it is only fair to add that this has been realised by all parties. The trouble mainly is that there is an enormous number of television patents, and opinions vary very much as to their relative values.

The whole business was made the more complicated by the fact that the type of reception apparatus is often largely tied up with the principles adopted in the transmission. This situation was never encountered in ordinary broadcasting. Whatever the transmitter, any one of a hundred different varieties of receiving sets could be used with success. In television, it would be possible to render all the receiving sets useless by changing the transmission over to a different system. Such a situation will however, never arise without long notice being given by the B.B.C. This is what the Report had to say on that point :

" A more difficult situation would arise if a completely new system, requiring an entirely new type of receiving set, should be evolved and should prove on trial to be definitely superior to the systems already in use. In such a case it might be necessary to adopt the improved system, in the first instance, at new stations only, and to postpone for a time its adoption at the older stations.

For it is obvious that many persons would be deterred from purchasing television sets unless they had some assurance that these sets would not be rendered useless at an early date by a complete change in the transmitting system. No radical changes should, therefore, be made in the systems serving particular areas without reasonable notice being given by the British Broadcasting Corporation of the contemplated change. In the initial stages this notice should not be less than, say, two years. The Corporation would naturally consult the Advisory Committee on this point. While

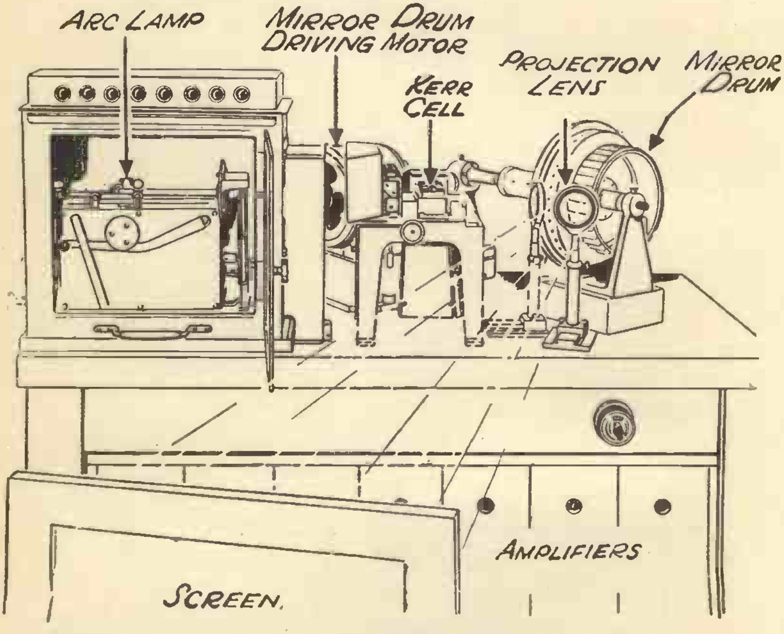
FIVE-CHANNEL TELEVISION TRANSMISSION



One of the notable advances in the progress of television was the development of the H.M.V. 5-channel method. The above sketch shows the transmitting apparatus employed. Details of the invention were first made known at the beginning of 1931 giving some reasonable measure of security in this direction, the aim should be to take advantage as far as possible, of all improvements in the art of television, and at the same time to work towards the ultimate attainment of a national standardised system of transmission."

Sponsored Programmes. The cost of the service, to begin with anyway, will come out of the Broadcasting licence revenue as we have already said. But at any time the B.B.C. has the power to accept sponsored programmes from advertisers. That is to say, a firm provides the programme and this is broadcast with discreet announcements that act as an advertisement for the firm.

AN "HIS MASTER'S VOICE" SYSTEM



The H.M.V. 5-channel receiver. The special purpose of the system was to enable films to be televised from one place to another and reproduced on a large screen. The picture was broken up into five sections by the transmitter, and each section was transmitted along a separate land line. The sections became blended into one complete picture at the receiver. The scanning was by means of a lens at the transmitter, a mirror drum being used for reception

Probably the announcement would never be any more flowery than something like this: "You will now hear and see a half-hour variety programme arranged by Messrs. XYZ, manufacturers of motor-cars."

For this the B.B.C. would receive no money, but they would be spared the expense of filling in the particular period covered. The B.B.C. has only very rarely used its powers in this direction, indeed of late years it has entirely avoided doing so. It remains to be seen whether the demands of television will cause it to broaden its policy.

" Selling Time " in America. In America, where there are no broadcasting licence fees and the broadcasting services are maintained solely on the revenues from advertisers, the development of television has been sadly hampered. " Selling time " has been a sound business proposition for ordinary broadcasting, but the same prospects are not to be seen in television. It has been calculated that to form a representative chain of high definition television stations in America, some eighty transmitters costing about eight million pounds would be required. And, so far, there has been no private capital available for the purpose, presumably because of the uncertainty of obtaining adequate returns. It would not be within the province of the government to make a move in view of the broadcasting constitution of that country.

As much or more money has been spent on television research and experiment in America as in this country, but we have the lead because of the national system of our broadcasting. It is also owing to the fact that broadcasting is on a national basis in Germany, that television has advanced in a practical direction there, too ; in fact, the Berlin high definition television transmitting station has been in service already for some considerable period.

But only in a rather experimental manner, and we think it can be safely said that our own television is the world's first attempt to place the new science on a firm basis of public entertainment. Therefore, we must all hope that the B.B.C. will continue to do its utmost to expand the scope of the programmes the while the technical side continues to grow.

Television and the Film Industry. It is not at all easy to fill in the television hours with first-rate material. Television programmes are more than twice as difficult to present as sound only programmes. Further, the same items cannot be repeated every evening of a week as they are in theatres and cinemas.

Yet, obviously, a television play equal to a first-grade talkie in its entertainment value would cost as much to produce, and for one or two broadcast " showings " that cost would be impossibly high. But there are thousands of films in existence which could not be shown again in cinemas which would provide grand material for broadcasting. However, although the cinema industry may not object to the use of these while television is receivable only by a relatively small percentage of the population, some opposition may reasonably be anticipated when television comes within the reach of all.

It has been suggested that only obsolescent minor feature films and short excerpts from current major productions, together with short educational and comedy films should be televised, and that while these would provide the television service with considerable programme material, the cinemas, with their current major releases, would be benefited rather than injured by their transmission.

Against this there are many who suggest that the television service ought to be provided with the best of everything, and the cry that " Vested interests must not be allowed to prevent progress " is already being heard. If the cinema industry can be defined as a " vested interest," it should in all fairness be pointed out that it has spent tens of millions of pounds every year for a quarter of a century or more to build up what deserves to be styled an international amenity, and has created remunerative work for hundreds of thousands of people in the process. Television will have to be able to make similar claims before it has the right to be held as an equal rival.

Surely a happy compromise is possible whereby television and the film industry can work together to the full advantage of both ? It has been found possible for this to be done in the case of radio and the gramophone, and in other instances, too, where antagonism at first existed.

Vision Extended Beyond All Horizons. To be able to sit in the quiet and comfort of one's own home and see and hear a full length talkie is an alluring prospect, but there is much more that television is able to bring you. Much fun has been poked at the " infliction " of the features as well as the voices of broadcasters on the public. Well, all human faces may not conform to recognised standards of beauty, but to the intelligent man or woman every one can be interesting. And as we believe that the intelligent ones are in the majority, and as we do not share with certain others the view that the average person, the man in the street, is little more than a " nitwit," it is our opinion that the seeing as well as hearing of a proportion of broadcast artistes and talkers alone constitutes good programme material.

There are also the many sporting events which can and will be televised, and we can think of no better illustration of the value of television than that of the broadcasting of civic events. The sounds and speeches emanating from the opening of this or that by a big personage, or the launching of a ship, are fairly frequent broadcast items. Well, some of us may tend to yawn at times when we find ourselves listening to such things, but the addition of sight would give us something to look at during the more tedious moments!

But the case for television is so obvious that we need not pursue the theme. If anyone in your presence tends to belittle it, ask him if he has ever really considered the blessings of sight, if he keeps his eyes shut at the cinema, if a blind listener isn't to be pitied? The use of that word "blind" will emphasise the wonder of television, for those who have eyes shall in truth see, and if they have imagination they cannot fail to marvel at the wonders of this modern miracle and appreciate the privilege of having their vision extended beyond all horizons.

Chapter 3

GENERAL CONSIDERATIONS

A SPECIAL SUMMARY OF THE PROBLEMS OF RADIO VISION BY SIR OLIVER LODGE, F.R.S.—HEARING AND SIGHT—BIRTH OF THE CINEMA—ACTION OF THE EYE—TELE-PHOTOGRAPHY—HARNESSING THE ELECTRON.

The transmission of pictures must be always much more difficult than the transmission of music or speech ; for sound is essentially a sequence, the ear appreciates only one note at a time ; whereas vision appreciates an immense number of impressions at the same time. Hearing is only a sequence, while vision is a simultaneity as well as a sequence.

Hearing and Sight. It may and will be said that surely an ear appreciates a harmony of simultaneous sounds. So it does, but it does it by analysing one note—if we correctly use the word " note " to signify a definite mode of vibration however complex, whereas the word " tone " signifies a simple vibration of definite pitch. A note may be composed of any number of tones, and the inner ear has a construction which enables it to analyse a note into its constituent tones.

But it does not receive those tones separately ; it receives only a single complex vibration, which could be transmitted to it through a single rod, or through the contact of a single point on a diaphragm ; as indeed we are familiar with in the gramophone, where the tones of a whole orchestra are transmitted as a single complex vibration through a needle point. The ear it is which sorts out that complex vibration and analyses it into the harmony of simultaneous tones.

There is thus no difficulty encountered or any problem to be overcome in the transmission of simultaneous impulses ; they all travel together as a single group ; and in that form they enter the mechanism of the outer ear ; they are not analysed until they get inside.

With the eye it is different. Every point or small element of the retina is a separate receiving station, and they are all at work simultaneously; so that every patch of luminosity on an outside object produces its own impression independently of the rest; and thus a picture or a landscape can be appreciated as a simultaneity.

Birth of the Cinema. If an object looked at moves, it can also be appreciated as a sequence, because when the stimulus ceases at any one place the nerves almost instantaneously, though not quite, cease to respond; so that if the illuminated patches are moving about outside, the corresponding images will be moving inside the eye, and different receiving stations will receive them one after the other.

That is not so with a photographic plate. There the impression one produces is persistent; and if the outer objects move, the result is mere confusion.

Consequently, though it is easy to project a moving scene or landscape upon a screen, as in the camera-obscura, just as it is done in the eye, it was not easy to photograph a moving scene so as to project it upon a screen; and about thirty years ago it could not be done. Strictly speaking, it is not done now. What is projected is a series or sequence of pictures, not quite alike, but following each other so closely that the illusion of continuous movement is produced from the series of jerks or intermittent illuminations which are really supplied. Each impression on the eye lasts long enough to merge into the one that follows it, without any necessary flicker or variation in the intensity of average illumination.

The problem before television is how to transmit such a moving scene or picture to a distance. And, considering that the projection of moving pictures themselves is a recent invention, it is not surprising that the reproduction of them at a distance is a difficult problem.

Action of the Eye. The outer part of the eye, the lens and chamber with the various adjustments, are very like a photographic camera; but the retina differs in innumerable ways from a photographic plate, for not only can it appreciate moving objects by reason of the small persistence of vision, but each point of the retina is a receiving station, capable of attunement to three different wavelengths simultaneously—the red, the green, and the violet—and can thus appreciate a compound impression.

Unlike the ear, however, it does not analyse this impression into its constituents; it merges them into one, which may be quite different from either separately. It is quite capable of appreciating a single wavelength, like our ordinary wireless stations, if a pure or simple red or green or violet is incident upon it. But if it receives more than one it fuses them into another sensation altogether, so that if it receives red and green simultaneously it gives a sensation called yellow. While if it receives all three impressions simultaneously it gives us what we call white.

Telephotography. By artifice even these devices can be imitated artificially, as we know in colour photography and the three-colour process. But the eye does everything so simply and easily that we fail to realise the wonder of it, until by long-continued experiment we find how difficult it is to transmit a clear impression of moving objects, even though we have eyes at the distant end to do most of the work and to give our crude experiments every chance.

The easiest thing to transmit telegraphically is a static picture or engraving, which may be built up by a number of dots, and these dots might be transmitted simultaneously and reproduced as a mosaic at the distant end by the use of a multiple cable with as many wires as there are dots. I do not say it is easy to do that, for I made attempts in this direction about fifty years ago with the use of selenium, and found it very difficult. Still, a more pertinacious experimenter might have succeeded. Transmission of a mosaic by multiple wires is imaginable.

But how are we to do it by a single wire, or, what comes to much the same thing, without a wire at all through the unlimited ether? We cannot hope to transmit the dots simultaneously; we must transmit them as a sequence.

We can imagine a point travelling over the picture, taking one element at a time, and reproducing a patch of corresponding luminosity at the distant end. The moving point need not travel quickly; the thing to be transmitted is steady and constant, and gradually a corresponding reproduction at the distant end can be built up. The process requires ingenuity and invention, but, as everyone knows, it has been done, both with a communicating wire and without, so that excellent portraits have been received at a distance. Well, that is one step towards television, though only a very early step.

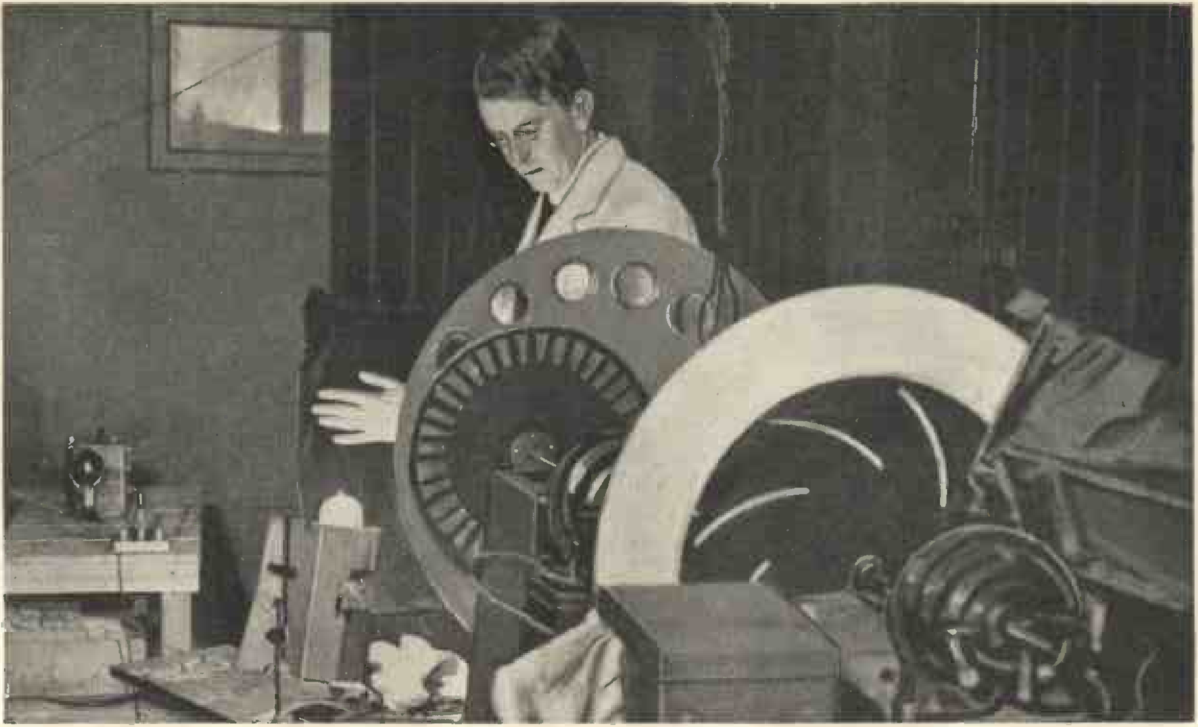
Harnessing the Electron. Now let us consider how to transmit a moving picture, either an actual person or an image of such person, or a landscape projected on a screen. We have now not merely a simultaneity to be transmitted as a sequence; we have both a simultaneity and a sequence to be transmitted together; and, as that seems impossible, we must contrive to move our points so rapidly over the picture that the image of each point at the

FOUR STAGES IN THE DEVELOPMENT OF TELEVISION

ON THE LEFT IS WHAT WAS SEEN AT THE RECEIVING END OF THE INAMINATE FIGURE USED BY BAIRD IN HIS FIRST EXPERIMENTS. BELOW, RIGHT, AN ATTEMPT WAS THEN MADE TO TELEVISE A HUMAN FACE

ABOVE, AN EXAMPLE OF THE RESULTS GIVEN BY THE LOW DEFINITION SYSTEM EXPERIMENTALLY EMPLOYED BY THE B.B.C. RIGHT, HIGH DEFINITION RECEPTION WITH A MODERN CATHODE-RAY TUBE VIEWER (APPROXIMATELY 180 LINES)

Plate 1



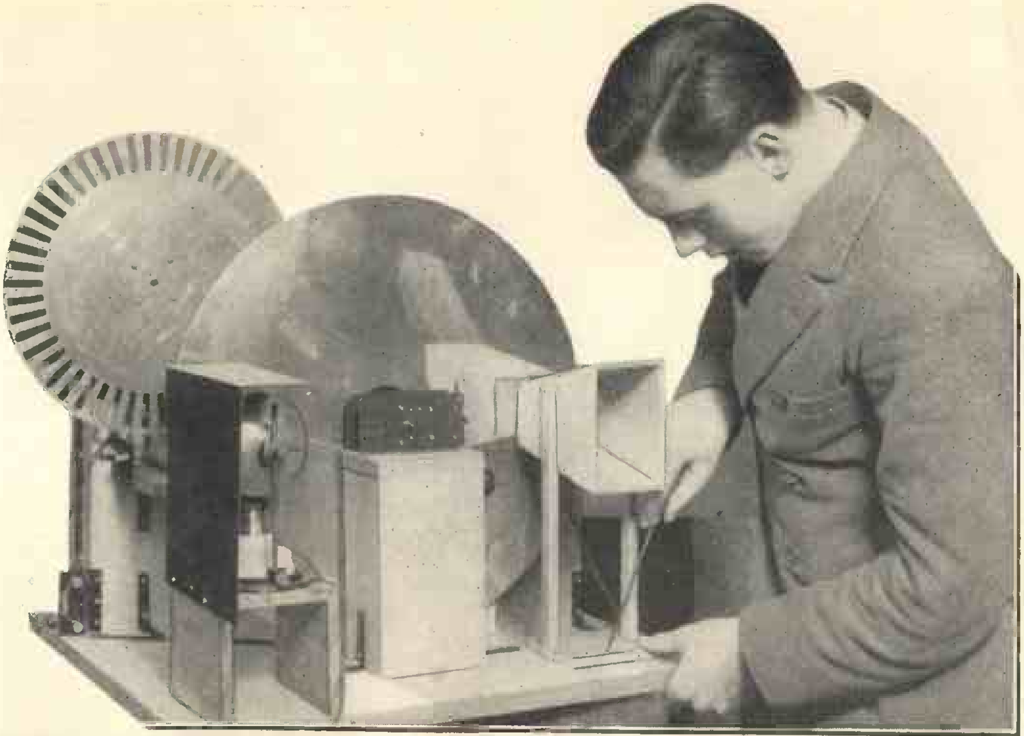
BAIRD, THE BRITISH TELEVISION PIONEER, AND HIS ORIGINAL LOW-DEFINITION DEMONSTRATION APPARATUS

Plate 2

MARIA GAMBARELLI, AMERICA'S FOREMOST TELEVISION STAR, IN THE HEAVY MAKE-UP NECESSARY TO PRODUCE THE BEST EFFECT WHEN COLOUR-SELECTIVE PHOTO-CELL UNITS ARE USED IN TRANSMISSION

Plate 3

Plate 4



EARLY APPARATUS USED FOR DEMONSTRATING THE PRINCIPLES OF THE TRANSMISSION AND RECEPTION OF LOW DEFINITION TELEVISION

A BACK VIEW OF THE BAIRD TELEVISOR FOR LOW DEFINITION TELEVISION. ON THE LEFT CAN BE SEEN THE NEON LAMP IN FRONT OF WHICH RUN THE HOLES IN THE ROTATING SCANNING DISC

THE BAIRD TELEVISOR WHICH WAS SOLD FOR THE RECEPTION OF THE LOW DEFINITION PROGRAMMES. THE OPERATOR IS SEEN ADJUSTING THE FRAMING OF THE PICTURE

Plate 5

THIS WAS THE FIRST COMPLETE CATHODE-RAY TELEVISION RECEIVER TO BE DEVISED AND MADE IN THIS COUNTRY. IT WAS PRODUCED BY THE TECHNICAL STAFF OF "POPULAR WIRELESS," THE LEADING RADIO JOURNAL distant end will not have faded from the retina before all the others have been projected on it likewise. The time of persistence of vision depends partly on brightness, but it is comparable with from one-twelfth to one-sixteenth of a second.

Hence if in, say, one-twelfth of a second the tracing point can move all over the picture without missing any salient detail, then the images at the distant end successively produced may be perceived by an eye as if they were all simultaneous. In other words, an illusion of simultaneity may be produced.

It appears impossible to move a material object at the necessary rate. But the stream of electrons available in the cathode-rays are sufficiently docile to enable a process as rapid as that indicated to be achieved. We have the free electron in enormous numbers at our disposal, as is emphasised in the Tenth Faraday Lecture given by Mr. C. C. Paterson and published in the Proceedings of the Wireless Section of the Institution of Electrical Engineers for March, 1935. Wonderful things in the way of illumination can already be carried out by this process, and it only needs a little more invention to make television by this means practicable.

Chapter 4

BROADCAST TELEVISION

THREE YEARS' PRODUCTION—THE NEW ART FORM—" CLOSE-UPS AND LONG-SHOTS "—MAKE-UP TROUBLES—SPECIAL COSTUMES — EARLY PROGRAMMES — ESSENTIALLY VISUAL ACTS — THE CAPTION MACHINE — SCENERY — STUDIO " ZONES "—PROJECTION FINESSE—CONSIDERABLE REHEARSING NEEDED—ACTUALITY TELEVISION—ADAPTING THEIR ART—STRIKING POSSIBILITIES—CULTURAL VALUE—WHAT ABOUT NEWS ?—INFINITE SCOPE FOR IMAGINATIVE PRODUCTION.

In this country broadcast television—*à la* B.B.C.—dates from the memorable night of August 22nd, 1932, when the first public television programme was radiated from Broadcasting House, London.

The sound part was sent out from Midland Regional, the accompanying vision from London National. The programme lasted from 11 to 11.30 p.m. J. L. Baird was seen and heard—as was fitting for the British pioneer of television—introducing the B.B.C.'s first sound and vision entertainment.

Looking back, that programme seems somewhat limited. But then so was the money allotted to television development. So, too, was knowledge of the needs of this new art form. Indeed, it was the B.B.C.'s realisation that it might equip itself with artistic experience that made the start possible—at a time when the entertainment value of the low definition pictures was admittedly poor.

The New Art Form. A television director was appointed to explore the new art form, to prepare the way for the inevitable time when television would materialise from the laboratory stage to millions of homes throughout the land.

Eustace Robb was the man—and he saw his moment. As television producer of nearly three years' experience, he can claim to have rather more than an inkling of the infinitely varied possibilities of this art of seeing and hearing by wireless. From that very first programme in that very cramped little studio, BB, down in the basement of Broadcasting House, we have watched with intense interest the gradual unfolding of a vastly varied number of applications of the television art.

To Mr. Robb we are indebted for an ever ready courtesy in explaining his aims and methods of achieving them. Without his unfailing patience we should never have been able to blunder about in the darkened atmosphere, first of studio BB at Broadcasting House, and latterly in the new television studio at No. 16, Portland Place.

Honours done, let us try to give you some idea of the story of the art—as distinct from the science—of television as it has been studied and developed by the broadcasters. Let us take you from that first programme, wherein Betty Bolton, Fred Douglas and Louie Freear earned a unique niche in television history, right up to the exciting possibilities of the B.B.C.'s latest high definition transmitter.

Close-Ups and Long-Shots. Can you imagine yourself trying to put over the first television programme? The difficulties were enormous. For one thing, the cramped studio—intended originally for the dance band—was practically in darkness, save for the eerie flicker of the scanning light. Only a limited movement of the artistes was possible, owing to inherent troubles in merging " close-ups " with " long-shots." Picture definition was so poor that the producer had to distort normal acts in order to bring in a preponderance of " close-ups," which obviously had more entertainment value than the indistinct " long-shots."

Nothing at all was known about the special needs of make-up. The electric eyes of television—the photocells—were known to discriminate against certain colours, but only experience could show how to counteract this effect.

Make-up Troubles. The inherent crudity of the picture made it necessary to elaborate and intensify normal make-up in a way that a first sight of the television artiste could be quite terrifying, not to say revolting. Under the robot electric eye it was found that the red and infra-red end of the spectrum produced the greatest effect, with the distressing result that reds tended to come out white. This led to some startling effects, the early pictures giving the ghastly appearance of de-composition.

Very soon the eye grows used to watching artistes with dark blue lips, with dead white under the eyes where deep shadows normally appear, and with perhaps a blue or purple shaded nose. These devices form the basis of the present television make-up, but with the higher definition television technique and better lighting there is no doubt that make-up will be modified, until it is no more bizarre than on, say, the film set.

Special Costumes. Costumes had to be treated for the same reason as faces—to counteract the peculiar way electric eyes look at things. Large areas of black had to be broken up with slashes of white. As the background was white, large areas of white in the costumes had to be edged or trimmed with some darker material—otherwise with such a crude picture the contrast would not have been great enough for lookers to pick out the outline.

These were some of the very first difficulties that Robb had to contend with. As he said: "We must borrow from existing art forms and adapt ideas for television. It is no use simply copying, though, for we are dealing with an entirely new art form."

From the very first programme already mentioned, progress along real television lines was rapid. The "news" value of television was strikingly shown when the Atlantic flyers, Amy and Jim Mollison, came in front of the scanner for pioneer lookers to see.

Early Programmes. In that restricted studio came a host of acts specially devised for television. Performing seals, ju-jutsu exhibitions, dancing acts—and then a television art show, to which Lord Lee of Fareham brought costly jade, silver and glass from Christies. Another striking programme was a mannequin parade—something so essentially of the stuff of television that it caused quite a stir.

By that time the technical side of television—always the underlying limit to artistic expression, remember—improved more than anyone had hoped was possible. The difficulty of merging long-shots with close-ups was overcome—and that alone made all kinds of new acts possible. The line connecting the Broadcasting House studio with the London National transmitter at Brookman's Park was "cleaned up" for its television signals, and that again improved the clarity of the picture.

Improvements in the power of the electric eyes to "see" made better lighting possible, and with that an intriguing vista of shadow effects was introduced, such as silhouettes, high lights, floor shadows, distortion of scenic shadows and the introduction of the artiste by his own shadow.

Essentially Visual Acts. By 1933 essentially visual acts were predominating the scene. Skaters, trick cyclists, dog shows, animals from the Zoo, eccentric dancers, ballet dancers—every conceivable kind of act appealing to the eye was tried.

Up to the middle of that year the background scene was somewhat limited. This was partly due to the lack of definition, partly to the prohibitive cost of a large stock of scenes, and partly to lack of facilities for scene shifting.

The Caption Machine. But then came the caption machine, as it was called. By means of this ingenious device the scope of production was greatly enlarged. A small disc type scanner explores an area of 4¾ in. by 2¼ in. and in this space all kinds of miniature scenes as well as captions and announcements can be contained.

The resulting picture is then merged with or superimposed on the main picture, being produced by the mirror drum scanning the studio scene. The looker can detect no difference between the large and small areas, of course, because he is looking at his screen at the far distant point.

The greatest single step forward so far as B.B.C. television production is concerned was the move from the restricted space of studio BB in Broadcasting House to more spacious quarters at No. 16 Portland Place—a few doors away from the main building.

A B.B.C. TELEVISION STUDIO

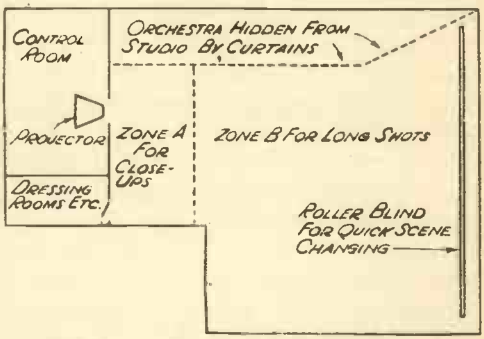


Fig. 4.—The layout of the television studio at 16, Portland Place, adjacent to Broadcasting House

(Photographs of various sections of the studio and control room appear on the art plates in this book.)

A plan of the new studio is shown in Fig. 4—and it will perhaps be interesting to study this in some detail. The studio space itself is rather an odd shape, being wider at the screen end than at the projection end.

There are several interesting points worth noting. They apply to present technique, of course, and may have to be seriously modified under the new conditions. The control room is seen at the left, inter-connecting with the studio by a large glass observation panel, through which the scanning projector is fitted. The orchestra is curtained off at one side of the studio—so that the light from the music sheets shall not be picked up by the all seeing " eyes."

Scenery. At the end of the studio is a roller blind or screen. This is fitted up about one foot in front of the long-shot wall, as the end of the studio is referred to. Behind its white protection different painted scenes can be erected while the programme is in progress, and a studio " fade " of ten seconds is all that is necessary to change from one scene to another. Only quite simple scenes have been provided so far—but by a judicious use of the caption machine, all kinds of apparently " expensive " effects have been obtained.

Studio " Zones." During our peeps into the Portland Place studio we have noticed that they refer to different " zones "—and the diagram shows exactly what this means. The projector cannot cover close-ups and long-shots at one go, but needs a change of lens as the artiste moves from one zone to another.

Scanning and lighting can be done over the large section of the studio marked as Zone B without any change in the projector. This allows quite a lot of latitude for dancers and so on, although there are other limitations.

In Zone A, where close-up shots are taken, the projector has to be adjusted by the insertion of a suitable short-focus lens, and for this reason the producer found it convenient to zone his studio accordingly.

When the artiste changes from a long-shot to a close-up some kind of intermediate device has to be thought out to cover the short break in the continuity of the programme. An artiste may have been dancing, and then want to come closer for a song, for instance. All kinds of dodges are devised, such as fans, muffs and veils, behind which the artistes temporarily retreat while the projector man slips in his lens.

Projection Finesse. That projector man has much more to do than anyone else during the actual show. His job is a sort of combination of the work of a movie cameraman and a cinema projection engineer. Certainly, during the many shows we have watched, he has had his hands more than full.

It must be understood that the projector in the control room is fixed, and cannot be swivelled up and down to follow vertical movements. The only thing that can be done is to raise or lower the scanning beam by moving a light mask up and down—and this is how the subject is normally kept at the centre of the picture.

The finesse comes in when changing from a Zone B picture or long-shot to a Zone A or close-up. The projection man has then to follow all the usual movements of the artiste by altering his focus as the televised subject approaches or draws back from the control room end of the studio. At the same time he is lowering or raising his mask on the projector in order to keep the subject central. Then, at a suitable moment, he slips in the lens for the change from long to close-shot.

The strain of this projection work in regular television transmissions of direct subjects—as distinct from the infinitely easier process of scanning films—will no doubt prove considerable. When one comes to think of it, the job is much more onerous than any similar job in allied arts. After all, if the movie cameraman makes a mistake he can always ask for another " take "—and the job of projecting films in a cinema is relatively simple once the process is understood. But with broadcast television there is no room for mistakes—and no chance to " do it again " if a mistake is made.

Considerable Rehearsing Needed. This question of the vulnerability of television to human error is one we do not want to over-emphasise just now, although it will no doubt arise from time to time. The modern film, with which television has so inevitably always been compared, has the tremendous advantage of preliminary " subbing " before the public ever sees it. Mistakes are made in the process of producing the film, but the public does not see them because they are remedied by a re-take or by cutting out the affected part.

As none of this can be done with an instantaneous television broadcast, it is obvious that the productions must be highly rehearsed, so that the possibility of human error is reduced to the limit. Even with the relatively simple shows of half an hour that Robb originally put over an immense amount of time has had to be spent in rehearsals—particularly in getting the cues right.

All of which points to the relatively expensive nature of direct television shows, such as have been produced in embryonic form in the early years by the B.B.C. Whether this factor will swing the broadcasters over to films—when they can get them—is perhaps an interesting speculation.

Actuality Television. We are perfectly certain that most lookers will want as much " actuality " television as possible. For some considerable time this is bound to be limited, as is the very nature of the material broadcast. By that we do not mean that the scope of subject will be limited—on the contrary we will presently sum up the broad divisions into which televised material falls—but rather that special treatment will have to be adopted

As an example we cannot do better than quote dancing—assuredly one of the most popular items of " actuality " television as thus far achieved. Mr. Robb found that an almost entirely new technique in dancing has had to be insisted upon for television purposes.

Even with high definition television of 240 lines it is still true that the close-up is of much greater interest than the long-shot, for even if the long-shot has quite good detail its subject is rather small on the average television set's screen.

Adapting Their Art. Thus the technique that has been evolved for 30 line television in the studio has to be copied very largely with the higher definition system. This implies that the dancer, for instance, must be restrained from keeping for too long a period to a consistently long-shot. In other words, the dancer has to change the usual side to side technique as evolved for stage presentation to a backwards and forwards sequence, not only to give the appearance of " depth " to an otherwise flat background, but to give lookers a " look-in " at the details of a pretty face, figure, or costume.

Many famous dancers have shown their willingness to adapt their art to the special needs of television, including some of the most famous international members of the Russian Ballet.

Adaptation will have to be the watchword in practically every form of television broadcast.

Watching some typical commercial films run through a 240 line system is a salutary lesson in the different technique needed for broadcast television—not least being the need for a rapid change from long-shot to close-up. If the long-shot is maintained for more than a very short time, the eye becomes bored—partly with its inability to see so much detail, but partly with the general flatness of the picture.

It is a prime asset of the television producer that this point should be understood. At Broadcasting House the three years of preparation under the Baird experimental low definition system have laid solid foundations upon which the future television producers will be able to build, with the added advantage of higher definition pictures.

Striking Possibilities. We have been reviewing in memory the many-sided interests that Eustace Robb has tried to " televise " during his adventurous years as television producer for the B.B.C. From that review some striking possibilities have come to light. Upon these we will now dwell, for they constitute, we imagine, something like a forecast of what you will soon be enjoying in your television equipped homes.

Strangely enough, we shall not start with the obvious television subject—variety. Simply because it is an obvious subject we can safely leave that alone.

Cultural Value. Let us start with some of the unique cultural aspects of this new art. Take, for example, the televising of antique works of art. Even with the meagre detail of the 30 line transmissions it has been proved that the showing of such objects can sustain interest on the part of the looker.

The average man in his home is by way of being out of touch with museums—or of regarding them with boredom. Even if he has some faint stirrings of interest the chances of ever finding an entry into the world of antique art are extremely remote. By television a vividly-brought-home picture of some of the world's most wonderful works of art is made possible.

Pictures, glass, silver and furniture are only four of the many types of work that can be televised—that have, indeed, been televised already, and with complete success. So have antique and modern sculptures, not to mention all kinds of clocks.

Sport opens up vast fields for television. Take, as just one exciting example, the televising of physical culture. Imagine the finest instructors in the country coming before you to explain how to do the daily dozen!

Boxing matches lend themselves very well to television, as both the B.B.C. and the Baird studios have shown. The confines of a boxing ring are just right for the television screen—every listener getting a highly prized ring-side seat. Wrestling and ju-jutsu are allied sports that, by their dynamic nature, are just the right "stuff" for television. Again this is not mere conjecture. The B.B.C. has proved the possibility by actual experience on the 30-line scanner. Among other things it has shown that fencing is also practicable. In fact, any sport carried out in a fairly limited space, obviously, can be the subject of television from the studio.

Ballroom dancing, which has so vastly increased in popularity in the last few years, is another proved subject for television. The finest instructors can demonstrate before the scanner exactly how you, in your own home, should do the latest steps. One might forecast a great rise in the standard of dancing from this cause alone.

From ballroom to ballet dancing is a great step—but it is a step television can bridge with the most intriguing possibilities. To the average man the mere mention of ballet dancing conjures up a picture of precious young dandies gazing with rapturous enchantment at foreign artistes performing exotic gyrations on the stage. Yet in truth, ballet dancing is a wonderful medium of artistic expression—illustrating how beautiful movement can interpret fine music.

Movement—that is the life blood of television. And ballet dancing has already shown itself peculiarly adaptable to television. Famous exponents of every form of ballet dancing have come before the scanner at Broadcasting House and have, by painstaking adaptation of their art, opened up illimitable scope for future entertainment. When ballet music and dancing come into the home, ordinary people will discover an enchantingly new form of artistic enjoyment.

The "home page" element has not been overlooked. Women will be able to judge the latest fashions—mannequin parades already having been put over with complete success. Dresses and hats, straight from Paris, will be critically gazed upon by the women of the land—no matter how remote their town or village may be.

One can draw quite an important inference from this. If women are made conscious of the essence of good style through the medium of television, they are going to insist upon that standard of style—even though they may have to be content with a cheaper interpretation of it.

What About News ? Before we leave the purely cultural aspect of television, what about news ? This opens up delicate problems, admittedly. But even if there are attempts to impede television in the way that was done with sound broadcasting, the chances of visual " rapportage " are infinite. When Jim and Amy Mollison came before the television scanner on their arrival in England after flying the Atlantic, they did more than interest a few television pioneers. They came as a portent of the kind of excitement that television will bring almost daily to suitably equipped lookers.

Film stars landing at Southampton from Hollywood, celebrities of all kinds, these give lookers something essentially topical to look at. The function of television in news broadcasts cannot be overestimated. The only thing that may prevent it from becoming the force it should are the powerful vested interests.

And so to variety. All the present limitations of broadcast humour—limitations acknowledged by the producers, but never fully circumvented—disappear when facial expression can be added to word of mouth. The intimate type of variety seems to offer the greatest scope for the present stage of television development, if only because, as so much emphasised already to many, long-shots of " Dancing Daughters " would tend to become tedious in the small framework that the average television set offers.

Radio drama has evolved a technique of its own. Whether this will ever be lost—as the art of the silent film was lost when talkies swept the industry like a forest fire—cannot yet be said. For many years to come, sound broadcasting must exist side by side with the dissemination of sound and vision programmes. That reason alone tends to show that the radio drama will not be affected, although very possibly less effort will be made to adapt purely visual plays for sound broadcasting.

Infinite Scope for Imaginative Production. In this chapter, which is much too short to do justice to the title, we have been able only lightly to touch on some of the aspects of television we personally have come across in several years of interested and sympathetic study of other people's efforts. What we have aimed to do is to show, first, that television is a new art form, and will have to continue to develop on its own unique lines; and secondly that, even when it does that, the scope it offers to imaginative production is infinite.

If the cultural possibilities of television are exploited we can foresee a widespread raising of aesthetic standards. Even if television merely seeks to entertain it will be worth while; but when at the same time it brings unexplored avenues of human interest into the home of the ordinary man its true mission will be done.

A. H.

Chapter 5

CHANGING PICTURES INTO RADIO WAVES

THE FUNDAMENTAL FACT OF TELEVISION—COMPARISON WITH SOUND—LONG-DISTANCE TRANSMISSION—PRODUCING ELECTRICAL IMPULSES—PROPERTIES OF EYE AND EAR—TWO PROBLEMS—A SIMPLE " PICTURE "—HOW THE LIGHT IS MADE TO VARY—SCANNING—SYNCHRONISING—PERSISTENCE OF VISION—DEFINITION—DETAIL—NUMBER OF " LINES "—" APPARENT " DEFINITION—SCREEN GRAIN.

Television has been defined as " seeing at a distance." You may reply that this is what you do anyhow, even if you have never heard of television. You always " see at a distance," because the object you see must always be at a distance from the eye, the impression being conveyed to the eye from the object by means of light rays. In the same way you may say that you always hear at a distance, because the source of sound is never actually in contact with the ear drum and the sound must proceed from the source to the drum via some medium, usually the air of the atmosphere. But television is " seeing at a distance " in a different sense. Anyway, let us leave that for the moment.

It may help us in understanding the relationship between television and ordinary sight if we consider first the relationship between sound broadcasting and ordinary hearing—something we are more familiar with.

Comparison With Sound. The distance over which you can hear a sound depends, amongst other things, upon the loudness of the sound ; generally speaking, the louder the sound the farther away you will be able to hear it. But there comes a practical limit to the loudness of a sound which can be produced in the atmosphere and there is a practical limit to the distance over which ordinary sounds can be conveyed merely through the air. You might be able to call to a man at a distance of 100 yards, or, if you had a very loud voice, possibly at a distance of half a mile. It would be hopeless for two people to attempt to call to each other by means of atmospheric sound waves say from here to America ! But we *can* do so if we use radio or the telephone.

The way in which these great distances have been bridged by radio is very simple. We know that radio waves will travel enormous distances through the ether medium without appreciable attenuation. Consequently, if we can transform sound waves into radio waves, we have them in a form in which they can readily travel these immense distances, and, if we have means at the other end for re-transforming them back into sound waves, we have a long-distance " vehicle " to carry them to their destination. What we do in radio broadcasting is to pass the sound into a microphone, which has the effect of setting up electrical impulses corresponding to the sound impulses : the electrical impulses are then caused to modulate high-frequency electric waves sent out from a transmitter (Fig. 5).

THE TRANSMISSION AND RECEPTION OF SOUND

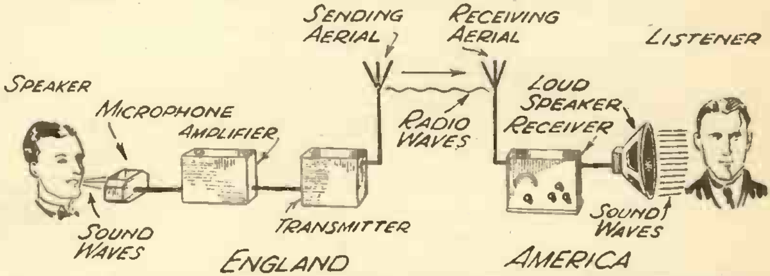


Fig. 5—Sound waves of speaker's voice affect the microphone, which transforms the energy into electrical impulses which are amplified and then transmitted by radio. At the other end, the impulses are received on the radio receiver and converted by the loudspeaker back to sound waves, and it is these that affect the ear of the listener

Long-Distance Transmission. At the receiving end these modulated electric waves are received on a suitable circuit which generates electric impulses corresponding to those which were generated by the microphone at the transmitting end ; these electrical impulses are then fed into a coil of wire wound round an iron core and have the effect of causing magnetising impulses, which operate on an iron armature placed in front of the iron core and cause it to vibrate mechanically and so to communicate actual sound vibrations to the air once more. So the sound waves have been put into a form suitable for long-distance transmission and are now back into sound waves once more. Here we have the complete cycle of operations from the time of speaking into the microphone in England and the time of hearing the voice reproduced in America. We have sketched the details of these various transformations because they will help us in considering the corresponding processes in television, but many readers of this volume who are radio users will already be fully familiar with the processes just outlined.

Now let us turn to television. Just as with sound, so with seeing, it is only possible for us to see by the naked eye (or even with a telescope) over a comparatively short distance on the surface of the earth, owing to the curvature of the earth and the fact that we cannot see beyond the horizon. In practice, the distance is much more limited than this, owing to the presence of obstacles, such as buildings, in the way of the direct line of vision. In a word, direct vision is for all practical purposes extremely limited in its range.

Producing Electrical Impulses. For long-distance seeing, therefore, we must have recourse to a process analogous to that which has already been described for long-distance hearing. We must first find some means of producing electrical impulses corresponding to the details of the picture or scene which is to be transmitted; secondly we can transmit these electrical impulses over practically any terrestrial distance, even through obstacles such as buildings which obstruct ordinary vision; and thirdly we must have some means of re-transforming the impulses at the other end of their journey and converting them back into light, so that we can reproduce the details of the picture or scene once more. The long-distance "link" over which the electrical impulses are sent may be in the form of a line conductor, such as a telegraph or telephone line or cable, or it may be in the form of a radio link, that is, the electrical impulses may be used to modulate high-frequency electric waves just as in ordinary radio broadcasting. We should mention

SENDING PICTURES THROUGH THE ETHER

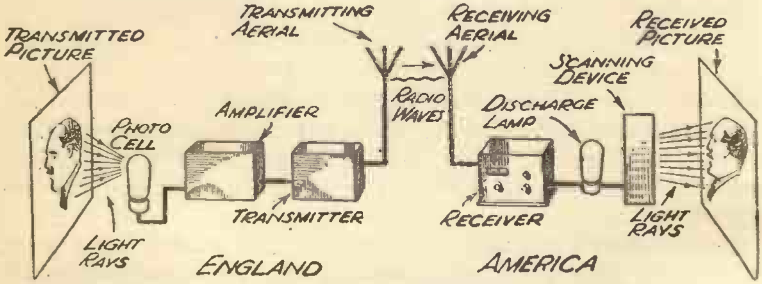


Fig. 6—Corresponding outline of television transmission and reception. Light rays from the transmitted picture affect the photo-electric cell, the electrical output from which is amplified and then transmitted. At the receiving end, the impulses are passed through a receiver, the electrical output of which affects a discharge lamp. The light rays of varying intensity from the discharge lamp are thrown into their respective positions on the receiving screen by means of the scanning device and the picture is once more built up

at this point that the term " television " or " true television " is nowadays commonly understood to mean seeing at a distance by means of radio transmission (Fig. 6). Sometimes television by the use of a radio link is differentiated from television by landline by the use of the term " radio television " or " radiovision."

Properties of Eye and Ear. Now we come to another comparison between sound and sight transmission which will help us in understanding the principles of television.

When you hear a sound your ear is only listening to one set of waves at any instant, the sound being drawn out along a time-line and so enabling the ear to concentrate on each particular part of it at the appropriate moment. Take any simple tune you know. You may be able to remember it perfectly well, but when you think of it you do not think of the tune as a whole. What you probably do is to start humming it, going through it from beginning to end and taking a certain time in the process. Now compare this with the mental process involved in conjuring up a picture or a person's face. Here your memory brings back to you the whole picture or whole face at once.

The fact that sound is normally heard a-bit-at-a-time, so to speak, aids us very greatly in transmitting sound electrically ; in fact it enormously simplifies the problem. And there is another condition which still further helps us. If a number of different tones or sounds are operating simultaneously, the corresponding sound waves combine to form a compound wave, which we can easily transmit electrically, and when this is reproduced at the other end the ear, by some marvellous property which it possesses, is able to resolve this compound wave into its different components and hear the different notes separately. Just how this is done is beyond our knowledge. But it is a very fortunate accident and very greatly simplifies the electrical transmission of sound.

Two Problems. When we turn to the question of transmitting vision, however, we find two fundamental difficulties to be solved. The first one is that the eye is not content to see the picture, at the receiving end, a-bit-at-a-time (as the ear was with sound) : the eye must see the picture all at once. The second one is that if we take electrical impulses corresponding to different parts of the picture to be transmitted, and lump these all together (as we do when transmitting a composite musical sound) the eye will be unable to " see " these all in their right places (as the ear did with the sound).

We do not know how to transmit a picture as a whole : all we can do is to transmit it a-bit-at-a-time, and follow up the successive bits so quickly that the eye " thinks " it is seeing them all simultaneously. In other words, we have to descend to playing a trick on the eye (" the quickness of the hand deceives the eye "). How we are able to do this we will explain as we go along.

THE MAXIMUM EFFECT

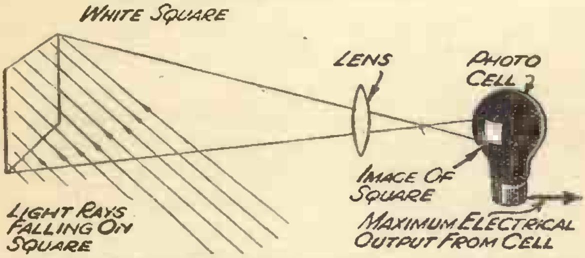


Fig. 7—Transmission of a simple white square. The light falling on the square is reflected and an image of the illuminated square is thrown by means of a lens upon the photo-electric cell. With the white square the electrical output from the photo-electric cell is a maximum

As regards fitting all the bits into their proper places on the receiving screen, since the eye gives us no help we have to fall back upon ingenious arrangements known as "scanning" and " synchronising " ; these will also be explained later in the chapter.

A Simple " Picture." Now let us go into the subject in more detail. Let us take the simplest possible case and suppose that we want to transmit a " picture " consisting of a plain white square with no markings on it whatever. To transmit this we need to have light shining on the picture, and then we must have an optical system (such as a lens) which will throw an image of the white square on to a device known as a " photo-electric cell " (Fig. 7). The photo-electric cell is described in more detail in another chapter, but briefly it is a device employing special chemical substances which are sensitive to light, and which change their electrical resistance according to the amount of light that falls upon them.

When used in suitable conditions the photo-electric cell gives an electrical output, the amount of which varies with the amount of light falling upon the cell. The photo-electric cell thus effects the transformation from light energy to electrical energy ; you will see that it corresponds exactly to the microphone in telephony, which takes us from sound energy to electrical energy. And just as the electrical impulses coming from the microphone are used to modulate the transmitting circuit, so the electrical impulses coming from the photo-electric cell (in television) are used in a precisely similar way.

You will see that the photo-electric cell, when the light from the white square is falling upon it, will give a certain electrical output, and this can be used to modulate a suitable transmission.

Now at the receiving end we will need something corresponding to a loudspeaker, but instead of turning the received electrical impulses back into sound, it will turn the received electrical impulses into light. If we have an electric discharge lamp (such as a neon tube) in which light is produced by an electric current passing through the rarefied gas in the tube, we can easily regulate the brightness of the light by regulating the voltage applied to it. This forms a convenient device for converting the received electrical impulses into light variations, because all we have to do is to use the received electrical impulses to control the voltage applied to this lamp.

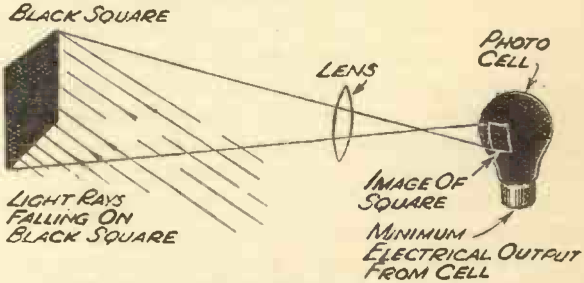

THE MINIMUM EFFECT

Fig. 8—The corresponding effect to that in Fig. 7, but with a black square. Here, only a small amount of light is thrown upon the photo-electric cell, the electric output of which is therefore at a minimum

In the simple illustration which we are considering, the effect of the " full light " from the white square which we are using as object will be, at the receiving end, to make the discharge lamp work " full on " ; if this discharge lamp is used to illuminate a small square receiving screen, the screen will show a plain square lighted with the maximum light. (Perhaps we should mention in passing that discharge lamps, as a rule, give lights of various colours; neon, for example, gives a red glow, and consequently the received picture of the white square would not be white, but would be whatever colour was given by the discharge lamp used. The point is, however, that the receiving screen would show " full light " when the object at the sending end showed " full light.")

If now we use a black square at the sending end instead of a white square (Fig. 8) it is obvious that the amount of light from this black square falling upon the photo-electric cell will be reduced to a minimum, with a corresponding change in the electrical output from the photo-electric cell ; at the receiving end the electric impulses will now reduce the brightness of the discharge lamp to a minimum, so that the receiving screen will show a black square (or something very dark, approximating to black).

The foregoing is a very crude illustration, but it lays bare the fundamental principles of television transmission. The idea is that the amount of light on the "object" is used to affect a light-sensitive or photo-electric cell, the electrical output from this cell varying in accordance with the brightness of the object: this electrical output from the photo-electric cell is used to modulate suitable transmitting circuits which send out over the ether electrical impulses corresponding to the brightness of the light on the "object"; these impulses are in due course received at the distant station by suitable receiving circuits where, in turn, they are used to control the light which is thrown upon a receiving screen; so the light on the screen at the receiving end is made to vary in exactly the same way as the light on the object at the sending end.

How the Light is Made to Vary. So far we have explained how the brightness of the light thrown on the receiving screen is made to correspond to the light reflected from the "object" which is being transmitted at the sending end. Since we have supposed the "object" to be a plain white or black square, we are only concerned with brightness of the light, and we have not yet come to the question of getting different degrees of light in different positions on the receiving screen. This is a complete new step in the technique which we must now consider.

Various ingenious methods have been suggested from time to time during recent years as to how a picture can be transmitted, but one that has stood the test of time and that seems to offer most scope for practical development is the method known as "scanning," and so we will proceed to explain what this process is.

TRANSMITTING A CHESSBOARD PATTERN

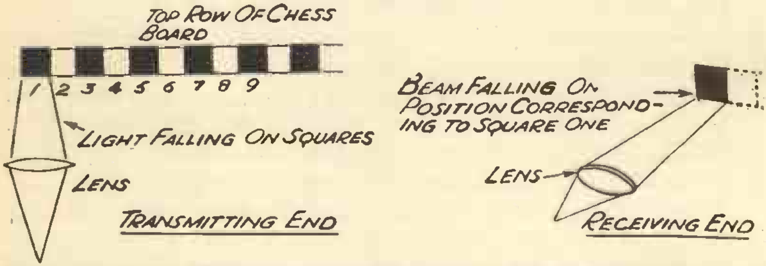


Fig. 9—The square of light at the transmitting end is resting upon square No. 1, and at the receiving end the beam of light is resting in a corresponding position on the receiving screen

Now bear in mind what we said earlier on about the eye: you will recollect that if a whole "bundle" of light impulses are presented to the eye at the receiving station, the eye has no means of separating them out and putting them into their proper positions to form a picture. If the eye is to build them up into a picture the different rays of light must be differentiated, either in position or in some other way, from one another so that they will of themselves (that is, without assistance from the eye) fit eventually into their proper positions in the reconstituted picture.

Scanning. To understand what is meant by " scanning " let us first of all think of the way in which you read a page of print. If you look at the page as a whole, the impression you get is not the same as when looking at a picture as a whole. It is probable that when you look at a picture you " take in " the main features of it without going over it and looking at all the details. But when it comes to a page of print you cannot perceive all that it contains by just looking at the page as a whole ; you have to start at the top left-hand corner and run your eye along the lines, proceeding along the first line and then going back to the left-hand end of the second line, finishing at the right-hand end, going back to the beginning of the third line and so on until you have read through the whole page. This process is precisely similar to that which is used in television for " scanning " a picture.

Let us take a very simple case in which the " picture " to be scanned consists of a chessboard pattern with black and white squares (Fig. 9). Let us suppose furthermore that a beam of light is being thrown upon this " object," and that the light-spot forms a square of light upon the picture, the square of light being exactly the same size as the squares of the chessboard. If we start at the top left-hand corner, as we did in reading a page of print, and if the square at that corner is a black one, then there will be little or no light reflected from the board. We will further suppose that a camera or such like optical system is focused, so as to throw a picture of the chessboard on to a photo-electric cell.

Now you will see that when the square spot of light is resting on the black square at the top left-hand corner, there will be little or no light falling on the photo-electric cell, and consequently there will be practically no electrical output from it for the purpose of modulating the radio transmission as described above. If the spot of light then moves one place to the right, so that it fits on to the adjacent white square, there will be the maximum amount of light passing through the camera lens and falling on to the photo-electric cell, and the maximum electrical output from this will be available for modulating the radio transmission.

Again, if the square spot of light moves on to the next square on the board, which is a black one, the light reflected and sent on to the photo-electric cell will be reduced to a minimum, and so on. Having now passed to the end of the first row of squares, the spot of light slips back quickly to the first square on the second row down, and proceeds along it in the same way.

Let us suppose that, by some means or other, the operator at the receiving end (which, of course, may be miles away) is able to throw an image of the discharge lamp at his end on to a screen (you will remember that this discharge lamp is going bright and dark according to whether the spot of light at the sending end goes on to white or dark squares) so that on the screen is a small square of light, which will be at maximum brightness when the beam of light at the sending end is resting on a white square, and which will go practically dark when the beam of light at the sending end is resting on a black square. Let us further suppose—and this is a very important part—that the operator at the receiving end is able to make the little square of light on his receiving screen shift along in position exactly the same as the spot of light at the transmitting end is shifting, so that when the spot of light at the transmitting end is resting on square number 1 the spot of light at the receiving end is resting in the position on the screen corresponding to square number 1; when the spot of light at the sending end moves to square number 2, the spot of light on the receiving screen moves to the position corresponding to square number 2, and so on.

THEY MOVE SIMULTANEOUSLY

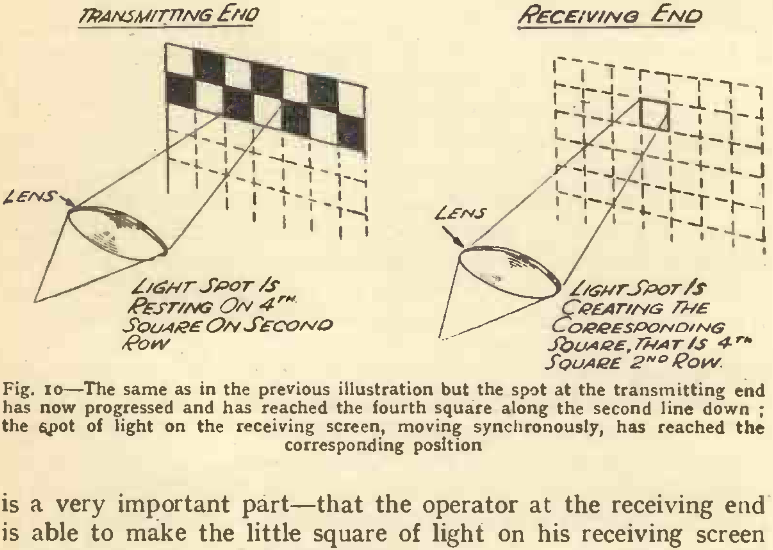


Fig. 10—The same as in the previous illustration but the spot at the transmitting end has now progressed and has reached the fourth square along the second line down; the spot of light on the receiving screen, moving synchronously, has reached the corresponding position

You will see that if this state of affairs can be achieved, the light-spot on the receiving screen will go through the same evolutions as that on the transmitted " object." It will pass along the " top line" of the screen, going alternately light and dark at the appropriate positions, just as the light-spot at the transmitting end is going over the white and black squares on the chessboard. Having come to the end of line 1, it will fly back to the left-hand end (or beginning) of line 2 and proceed in the same way (Fig. 10).

Synchronising. We will not in this chapter deal further with the arrangement by which the spot of light, which is building up the picture at the receiving end, is made to move and keep in step with the spot of light at the transmitting end. The process of keeping the two light-spots in step, and moving over their respective object and screen in exactly the same way, is known as "synchronising" and is dealt with fully in another chapter. Suffice to say for the moment that when the transmitting apparatus is properly synchronised, the position of the light-spot on the object or picture at the sending end will correspond with the position of the light-spot on the screen at the receiving end. For instance, if the spot on the picture at the transmitting end is, say, six lines down and half-way along the line, the spot on the screen at the receiving end will be six lines down and half way along the line at the same instant, and so on.

THE FIRST LETTERS FADE

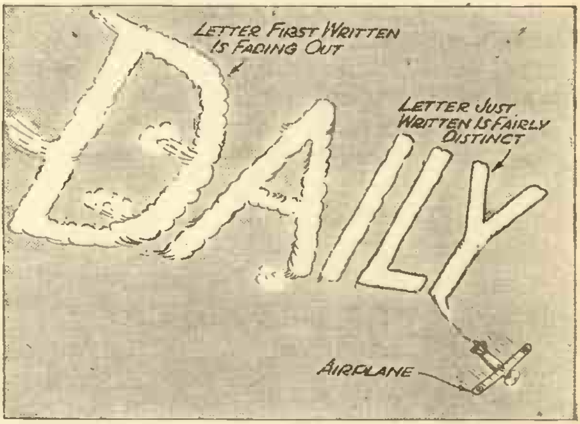


Fig. 11—The pilot has written the word "Daily," but, owing to the effect of the wind, the letters which were first written are fading out, whilst those which he has just done are much clearer. The same kind of thing happens with the light-spot which builds up the received picture in television. To avoid it, the light-spot must travel very quickly

Persistence of Vision. Now we must refer to a property of the eye itself by virtue of which a complete picture is seen on the receiving screen when this light-spot of varying intensity flies rapidly over the screen, tracing it along in lines as already described. You have probably noticed that if you look at a bright light for a second or two and then look away, or close your eyes, you can still see (in your mind's eye, as it were) the image of the light. It is not merely in your mind's eye but actually in your eye, and you are still really seeing the light, because its effect on the retina (that is, the sensitive part of the back of the eye) has not yet died away. When light falls upon the retina it causes certain temporary chemical changes which stimulate the nerve of sight, and when the light ceases to fall on the eye the retina resumes its former condition very quickly, but not instantaneously: there is a slight lag. Now this lag is called " persistence of vision," a term which explains itself.

If the spot of light at the receiving screen (which, you remember, is going alternately bright and dark as it runs along each line) moves quickly enough, the eye looking at the screen will see white and dark squares because the impression of the first white square will not have died away out of the eye by the time the second one appears in its position, and so on.

If the light-spot moves over the whole screen in a time which is less than the time required for the impression of the first white square to die out, then the eye will see a complete picture or reproduction of the chessboard pattern which is being transmitted. Obviously the more quickly the spot traces these series of line paths across the screen, and so covers the whole area, the more nearly will the eye see the whole effect as a complete picture, because the parts first traced out will have had less time to fade from the eye before the picture is completed.

THE PERSISTENCE EFFECT

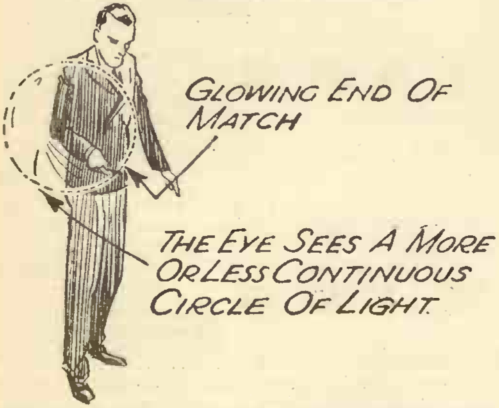


Fig. 12—The effect produced by waving a glowing match end. The eye sees a streak of light, owing to " persistence of vision ".

Perhaps we can give you a simple illustration here which will help to make this clear. No doubt you have all seen " sky-writing " by an aeroplane sending out a jet of smoke and performing evolutions so as to write the letters of a word. If there is any wind moving at the time, the letter which is first written will be all distorted and blown away by the time the pilot has completed the last letter

(Fig. 11). In a general way this corresponds to the effect on the television receiving screen. The whole picture must be traversed by the light-spot before the impression of the first part has had time to fade out of the retina of the eye.

You will realise that this means that the spot has to traverse the entire picture in a very short space of time, this time being no more than about 1/12th of a second. If the time is appreciably more than this, the early part of the picture is beginning to fade out of the eye before the last part is completed, and you get an effect similar to that when you wave a red-hot match end in the air, where you see a kind of red streak, bright at the advancing part and tailing off at the other end (Fig. 12).

You will remember that we said earlier that we could not transmit a picture as a whole, but had to transmit it in bits—" a-bit-at-a-time "—and to play a trick on the eye. Well, now you see what it is: the trick consists in sending the separate bits in such rapid succession that the eye thinks (so to speak) that they are coming simultaneously. You will notice that this is only possible by taking advantage of this curious property of persistence of vision. Without this faculty of the eye, goodness only knows how we should be able to achieve television at all!

Definition. It remains in concluding the present chapter to touch on the question of the definition in the picture, that is, the amount of detail which can be obtained in the received picture, corresponding to the details of the transmitted picture.

MAKING SHARP EDGES

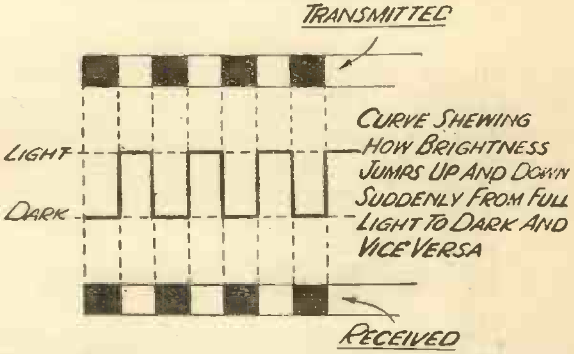


Fig. 13—If the scanning spot rested stationary upon one square of the chessboard pattern and then jumped instantaneously to the next square, resting awhile, then jumped instantaneously to the next square, and so on, the light would vary according to the " top hat " curve shown, and the received picture would have sharp edges similar to those in the original

Referring again to the chessboard pattern, you will appreciate that if the light-spot at the transmitting end went in jumps, being stationary for a fraction of a second on a white square, then jumping quickly to a black square and remaining stationary there for the same length of time, then jumping quickly to the next square, and so on, and if the light-spot at the receiving end did exactly the same thing, we should get, on the receiving screen, fairly sharply defined edges to the squares, that is, lines of demarcation between one square and the next (Fig. 13).

In practice, however, it is not practicable to make the spot jump and remain stationary between jumps in this way (there are quite enough technical difficulties without this), and what we have to do is to make the spot move continuously over the picture. Let us see what is the effect of this. Consider again the chessboard pattern. The light-spot is resting on a white square and moves with a uniform motion from that square on to the adjacent black square (Fig. 14). As it does so, the total amount of light reflected from the chessboard on to the photo-electric cell will gradually diminish from that of a full white square down to that of a black square; for instance, when the light-spot is halfway from the one square to the next, one half of it will be on the white square and the other half on the black square, and the amount of light reflected will be half that of the full white square.

The result is that the electrical output from the photo-electric cell, instead of going up and down in a series of jumps will go gradually up and down, according to a "curve" something like that in the accompanying figure. When this comes to be reproduced at the receiving end we shall get a white patch in one position and a black patch in the adjacent position, but instead of a sharp line of demarcation between the two we shall have a gradual reduction of the brightness from full white to black, passing through a kind of grey.

This means that instead of a sharply defined set of black and white squares in the reproduced picture

A CONTINUOUS MOVEMENT

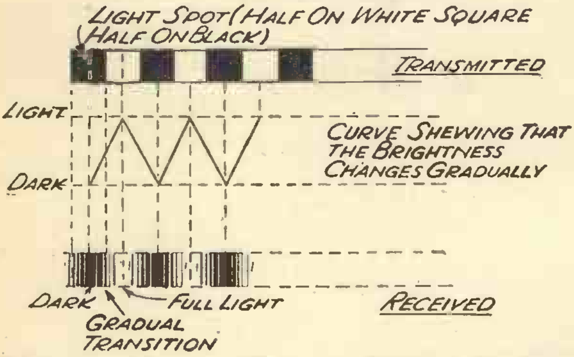


Fig. 14—The light-spot moves continuously. Here it is shown halfway between a black and white square, the brightness then being half the maximum. When it is full on the black square, we have a dark effect, when it is full on a white square we have full light. Consequently the received picture of the row of black and white squares shows black and white patches, gradually merging from the one to the other, but not sharp lines of demarcation

we shall have a kind of blurred effect, obviously intended for black and white squares, but the sort of thing a short-sighted man might see, or the sort of picture you would get if you took a photograph of it with the camera slightly out of focus.

Detail. From this you will understand, in a general way, what is meant by the " detail " in the reproduced picture. In the crude case given above, the " detail " will obviously be pretty bad. The question therefore arises : How can we improve the detail ?

Well, we can improve the detail by making the light-spot much smaller than the black and white squares (Fig. 15). This will remain " full white " in travelling across the white square, and the tumbledown in brightness when this small spot passes over the edge from a white square to a black square will occupy a correspondingly shorter time-interval ; things will then remain black whilst it is passing across the black square, and so on. At the receiving end this will sharpen-up the region of demarcation between a white patch and a black patch very considerably.

It is clear that the " definition " will depend upon the size of the scanning spot in relation to the size of the whole picture. But again, if we use a small spot like this, it will be all very well for passing along a horizontal line of these black and white squares, but what is going to happen when we reach the end of the first line and go back to begin the second line ? When this small light-spot runs along the top row of squares it will trace out a path which is much narrower than the row, and the light-spot at the receiving end (being made correspondingly small, which it must be) will trace out a black and white band, but the width of this band will only be equal to the diameter of the spot. When the scanning spot jumps to the second line, it will have omitted

WITH A SMALL SPOT

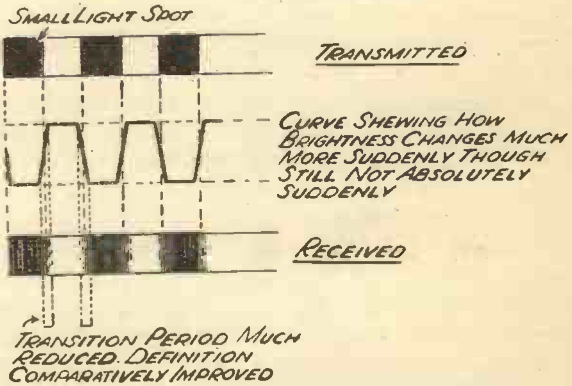


Fig. 15—If the scanning spot is made small compared to the squares, the region of demarcation is reduced, and we get a nearer approximation to the ideal condition of sharp edges between black and white

a large part of the area of the top row of squares. The reproduced picture will thus consist of a series of narrow bands, each a set of black and white sections it is true, but with wide spaces between successive bands.

To get over this, we must make the small spot start at the top of the first row of squares, go along to the end, then come back to the beginning and go along again a little lower down, but still on the first row of squares, and so on, until it has completely scanned the first row, before it begins on the second row (Fig. 16). The amount it descends each time it goes along will be roughly equal to the diameter of the spot. Suppose the diameter of the spot is one quarter of the depth of the squares, then the spot will have to make four successive traverses, descending a little each time, before it has traversed the entire area of the first row of squares (Figs. 16 and 17). So you see, making the spot one-quarter of the diameter means that we have to make four times as many traverses, or "lines" across the object.

FOUR LINES INSTEAD OF ONE

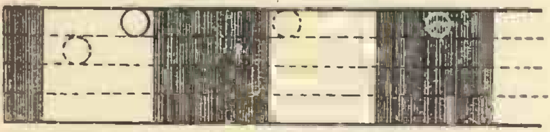


Fig. 16—To scan a row of black and white squares by means of a scanning spot much smaller than the squares, the scanning spot must make several excursions. Here is a spot the diameter of which is one quarter of the dimensions of the square

Number of "Lines." You will see from this what is meant by "definition" and by the "number of lines." In the "low definition" B.B.C. television transmissions a total of 30 lines is used, that is to say, the diameter of the light-spot is roughly 1/30th of the width of the picture, the width being reckoned in the direction at right angles to the traverse, and so the spot, when it has travelled across the picture in 30 adjacent lines or paths, has covered the entire area of the picture, after which, of course, it flies back to the starting point and repeats the same process all over again. We may, perhaps, mention at this point that in low definition B.B.C. transmissions the whole picture is traversed 12½ times per second or 25 times in two seconds.

If instead of using a chessboard, which we have taken as a convenient illustration for the purposes of explanation, we use now an actual picture, say a head and shoulders, precisely the same sort of thing will happen, and whenever the light-spot passes over a bright part a strong impulse will be sent out, and when it passes over a dark spot the impulse will be weakened, the strength of the impulse corresponding to the brightness of the particular part over which the light-spot is passing at that instant.

If the spot passes a " detail " on the picture which is about the same size as itself (for example, a button on the coat) it is evident from the foregoing that this detail will not come out clearly in the received picture; it will appear as a dark spot (if a black button) but the edges will be blurred and the detail will not be clearly defined.

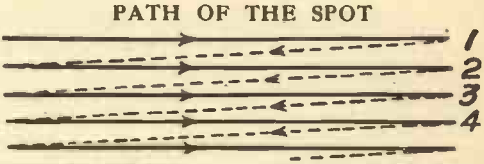


Fig. 17—This illustration shows the path of the scanning spot as it progresses over the screen. On reaching the end of a line it goes back to the commencement of the second one, and so on

If now we divide the picture into, say, 180 lines or paths, and use a comparatively smaller spot, we shall have to make the spot travel all that much faster (because it now has to rush across 180 lines instead of 30 in the same time), but we shall improve the " detail " because this very small spot can cope with a detail on the picture which is just that much smaller.

Now you know what is meant when you hear about " 30-line definition " or " low definition." When we go to say 100 lines or higher, we refer to " high definition." We need hardly add that the technical difficulties increase rapidly as the degree of definition, that is the number of lines, is increased. If it were not for this, of course, nobody would dream of using low definition.

" Apparent " Definition. It is rather curious that the apparent definition turns out to be better than you would expect, owing no doubt to some property of the eye (or the imagination) in making-up, or filling-in, the missing detail. You know how an artist will sometimes draw a picture consisting of a few strokes which, looked at closely, is meaningless, but, at a little distance, gives you quite a distinct impression, the fact being that the imagination unconsciously supplies what is omitted. Well, the same sort of thing happens with a televised picture, and this accounts for the fact that even on the present B.B.C. 30-line transmission you can get, in favourable conditions, a received picture which is remarkably good and recognisable, far better than you would expect from purely geometrical considerations.

" Screen Grain." In explaining the " definition " of a received television picture, it is customary to compare it to the definition of a screen-block used for printing pictures in a newspaper. No doubt you know that for the purpose of printing blocks, according to one process, the object is photographed through a " screen," so that ultimately the block which is made from the photograph has a large collection of small projecting " points," which when inked and printed give you a picture made up of corresponding black points with whites paces between. If the screen is very coarse you naturally get a correspondingly coarse picture, and if this is held close to the eye it may be scarcely recognisable, but it will become recognisable if held some distance away. If the screen is made finer, so that you have a large number of smaller points constituting the picture, then the "grain" of the picture is reduced and smaller details can be brought out; at the same time the picture will stand looking-at closer. It will be obvious that if there is a "detail" in the original object which is of the same size as, or smaller than, the "points" on the block, such detail cannot be reproduced.

TRAVERSING LINES

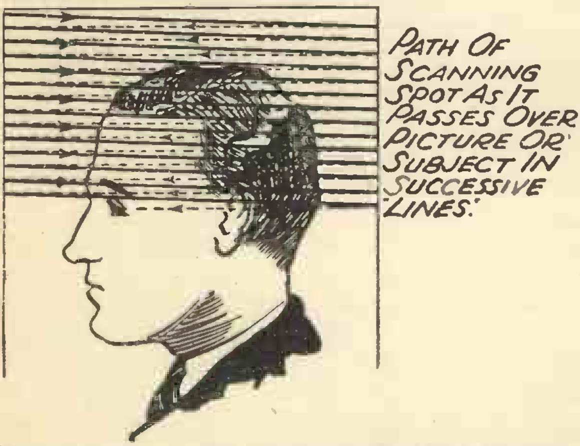


Fig. 18—Showing how the scanning spot traverses a picture or a "subject," being bright where the picture needs to be bright and dark where the picture needs to be dark, and so building up the picture

You should have now got a general idea of the basic principles of television transmission and reception. The various parts of the subject are dealt with in more detail in succeeding chapters, but it is necessary to have the broad scheme clearly in view.

Let me sum it up for you: Two men are sitting at separate tables in a room: one has a picture before him, in black and white, whilst the other has a plain sheet of paper and some black ink. The first man A moves his finger along the upper edge of the picture, and B proceeds along the corresponding upper edge of his paper. Every time A passes a dark part of the picture, he calls out, and B puts a dark mark on his paper. On coming to the end of the first "row" they both go back to the beginning of the second row and do the same thing all over again. If they keep in step with one another (synchronised) they will finish up at the bottom right-hand corner simultaneously, and B will find on his paper a set of black and white dots or patches, which form a crude copy of A's picture.

Let them do it all over again, only moving in finer lines (smaller dots made by B and more of them) and the " detail " of B's picture will turn out to be improved.

Instead of A and B doing all this, let it be done automatically at the A end, the " messages " being transmitted by radio, and let these messages automatically control the making of the light and dark parts at the B end. As light is used now, instead of ink, the impression will quickly fade away. All right, let us speed up the process so fast that the eye, looking at the B end, cannot tell but what it is a complete picture.

Now, here you have the system in brief, and although it may sound very simple to you, it has taken many years of patient thought and work to bring it to its present state.

Like many other things, it is simple in principle, but not quite so easy in practice. We must admire the ingenuity of its very simplicity !

J. H. T. R.

Chapter 6

WHY THE PICTURES MOVE

PERSISTENCE—THE CINEMATOGRAPHIC EFFECT—EFFECT IN THE EYE—DURATION OF THE "LAG"—THE "MOVING" EFFECT—A MAGIC LANTERN SPEEDED UP—"FLICKER"—PICTURE FREQUENCY—EFFECT OF DEFINITION—LINE FREQUENCY—ELECTRIC SIGNS—SCREEN PERSISTENCE—FLUORESCENT SCREENS—PHOSPHORESCENCE—BRIGHTNESS OF THE RECEIVED PICTURES—LIGHT AND SHADE.

It has been explained that the only practical way we know of for transmitting a picture by television is to transmit a series of impulses, corresponding to a set of points of light. What actually happens on the receiving screen, where the received picture is being built up, is that a spot of light flies over the screen in successive lines and the brightness of the light varies from point to point so that some points of the screen will appear dark and some points will appear bright. If this process were carried out slowly, the eye would see the spot of light as it travelled along the successive line paths, but if the speed of travel of the light-spot is so much increased that it traces the entire picture before the impression, in the eye, at the commencing part of the picture has had time to "fade out," then the eye will be unable to follow the spot, as a spot, and will see the picture as a whole. What we are really doing is to trick the eye into thinking it is seeing the whole picture at once, and this we are able to do by taking advantage of the curious property known as "persistence of vision." (See Fig. 19 for an interesting illustration of this principle.)

Persistence. If it were not for this, no matter how quickly we whisked the light-spot over the screen, the eye would still be able to follow it and would not see a complete picture. So you see that on this accidental property of the eye depends the process of building-up the received picture; without it we should have to look about for some different television technique.

The Cinematographic Effect. This question of persistence of vision is equally important in cinematography. Although you may not perhaps realise it, it is entirely due to this effect that you are able to see moving pictures on the cinema screen, instead of seeing what is in reality taking place and that is, a series of separate and distinct pictures separately projected.

In view of the fundamental importance of this property it is necessary to study it carefully in connection with television. We have seen in the previous chapter how if you strike a match and, when it is burning brightly, blow it out, leaving the end glowing, and then wave this about in a circle in a dark room, you will not see just the end of the match but you will think you see a continuous red circle. We have all done this kind of thing with fireworks and other objects and the effect must be familiar to everyone. Now this is a simple illustration of persistence of vision. What is happening is this. When the glowing match-stick is at one position the image of it is focussed by the lens system of the eye upon a certain position on the retina (that is, the sensitive part of the back of the eye). When the glowing match moves to another position, the image of it moves to a corresponding position on the retina, but if the glowing match is moving very quickly, the part of the retina on which the image was first focussed has not lost the effect before the image has moved to an adjacent position, and so the eye goes on seeing the image in its first position (and, of course, all intermediate positions) for a certain short space of time. The result is that all the various images connect up, as it were, or merge, and the eye sees, or thinks it sees, a continuous ring of light, whereas it ought to see what is actually happening, that is, a single source of light travelling around a circular path.

TRICKING THE EYE

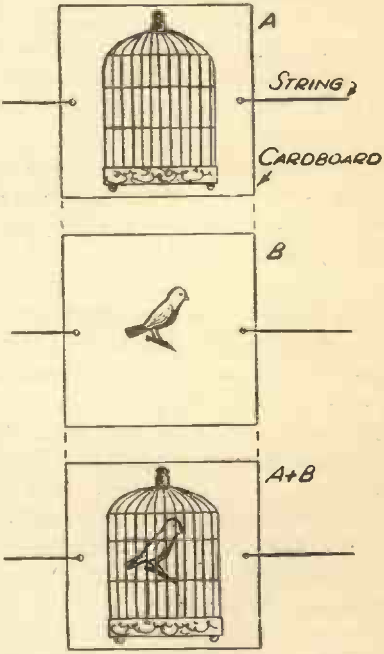


Fig. 19—An old experiment to illustrate persistence of vision. A piece of cardboard has a birdcage drawn on one side and a bird on the opposite side as shown at A and B. The card is held by strings threaded through two holes at the mid-points of the sides. When it is spun over rapidly you see the cage and the bird simultaneously and the bird appears to be in the cage

Effect in the Eye. We need not, in this chapter, go into details as to what actually happens in the retina ; in any case this matter is dealt with in more detail in another chapter. When light falls on the retina it causes certain chemical changes to take place, and these have the effect of stimulating the nerve of sight. When the light is extinguished the retina resumes its normal condition, but the change, either when the light commences or when it ceases, is not absolutely instantaneous. It is this slight lag which accounts for the persistence of the effect even after the light has ceased. A very minute and accidental effect you may think, and one which, in the ordinary use of our eyes in everyday life, never comes into evidence. Nevertheless, it is the basis, as already indicated, of cinematography and television. It enables the eye to be deceived by very rapidly moving objects and we take advantage of this defect in the eye—for a defect it undoubtedly is—and turn it to account for these special purposes.

Duration of the "Lag." The duration of the persistence in the retina (that is to say, the time required for the impression of a bright light to die away after the light has, in fact, ceased) varies with different people. Some people's eyes recover in a very short space of time, whilst some people will continue to see the impression of a bright light for a much longer time. If a light is exceedingly bright—for example, an electric spark, a flash of lightning or a flashlight used for photographic purposes—then practically all people will find the effect persist a long time and may even see it many seconds after it has actually occurred. Another curious thing about the eye is that its sensitiveness to light, as also the duration of the persistence, varies with the amount of light actually falling upon the retina.

For instance, during the day you experience no discomfort from daylight, but if you go into a dark room for an hour or so your eyes will become much more sensitive to light and if you then emerge suddenly into full daylight you will experience great discomfort for a few seconds, until your eyes have accustomed themselves. Also, if you see a flash of lightning during the daytime you will perhaps, scarcely notice it, but if you are staring out into a dark sky at night-time waiting for a flash, when it comes it will leave a very vivid impression in your eyes, because they have become much more sensitive owing to the darkness. Well, so much for the actual effect in the retina of the eye. Now let us see how it is made use of in the cinema film.

The "Moving" Effect. Most people have some idea how the continuous "moving" effect is obtained in cinematograph pictures. The pictures are thrown upon the screen by projecting a powerful

ONLY ONE TUNING CONTROL

A TELEFUNKEN TELEVISION SET OF ADVANCED DESIGN WHICH GIVES EXTREMELY GOOD RESULTS. THERE IS ONLY ONE TUNING KNOB AND WHEN THE SET IS TUNED TO THE SOUND CHANNEL, IT IS AUTOMATICALLY CORRECT FOR PICTURE RECEPTION. THE OTHER TWO KNOBS ARE FOR TONE AND VOLUME ADJUSTMENT. THE TUNING SCALE IS CALIBRATED IN MEGACYCLES

Plate 7

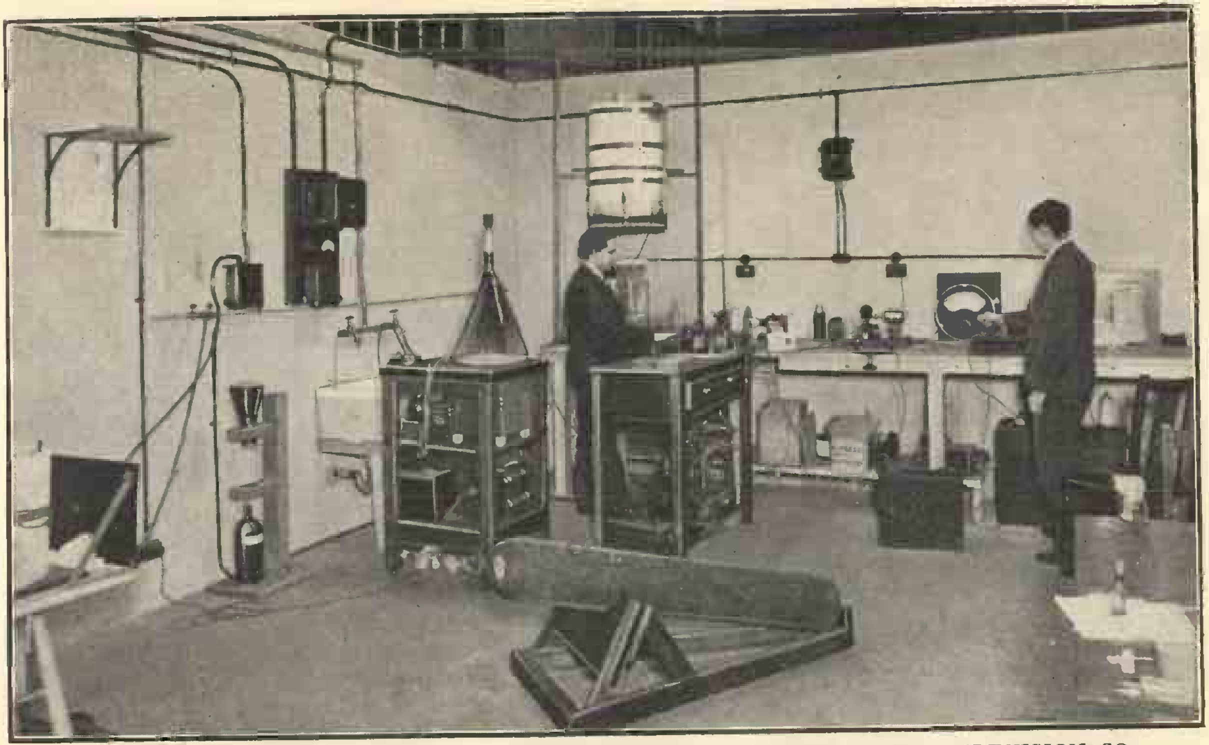
THE ULTRA-SHORT WAVE AERIALS ERECTED ON THE BERLIN BROADCASTING TOWER FOR THE TRANSMISSION OF HIGH DEFINITION TELEVISION

SIMILAR TO THE SCANNING ANALYSIS PRINCIPLE

THE PROCESS OF REPRODUCING " HALF-TONE " ILLUSTRATIONS IN NEWSPAPERS AND MAGAZINES IS IN SOME RESPECTS SIMILAR TO THE SCANNING ANALYSIS OF PICTURES WHICH OCCURS IN TELEVISION. AS THE MAGNIFIED PORTION ABOVE SHOWS, THE PICTURE IS BUILT UP WITH THOUSANDS OF DOTS, AND THE MORE THERE ARE OF THESE TO A GIVEN AREA THE BETTER THE DEFINITION

Plate 9

Plate 10

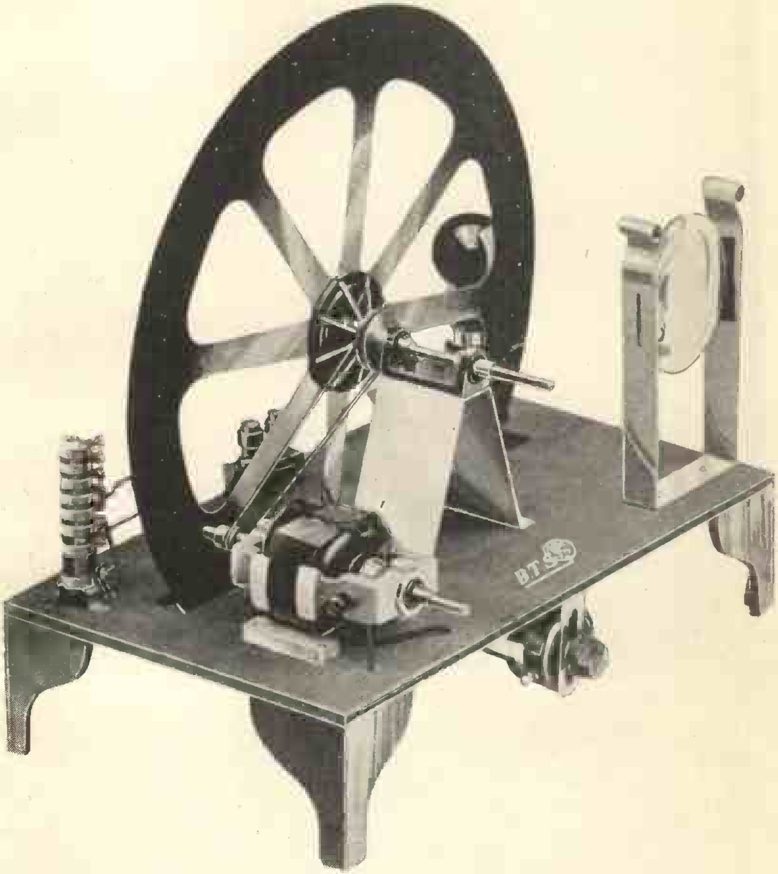


THE CATHODE-RAY TUBE RESEARCH LABORATORY OF THE BAIRD TELEVISION CO.

A TELEVISION-TELEPHONE ENABLING THE USERS TO SEE AS WELL AS HEAR EACH OTHER WHICH WAS DEMONSTRATED AT AN EXHIBITION IN MILAN

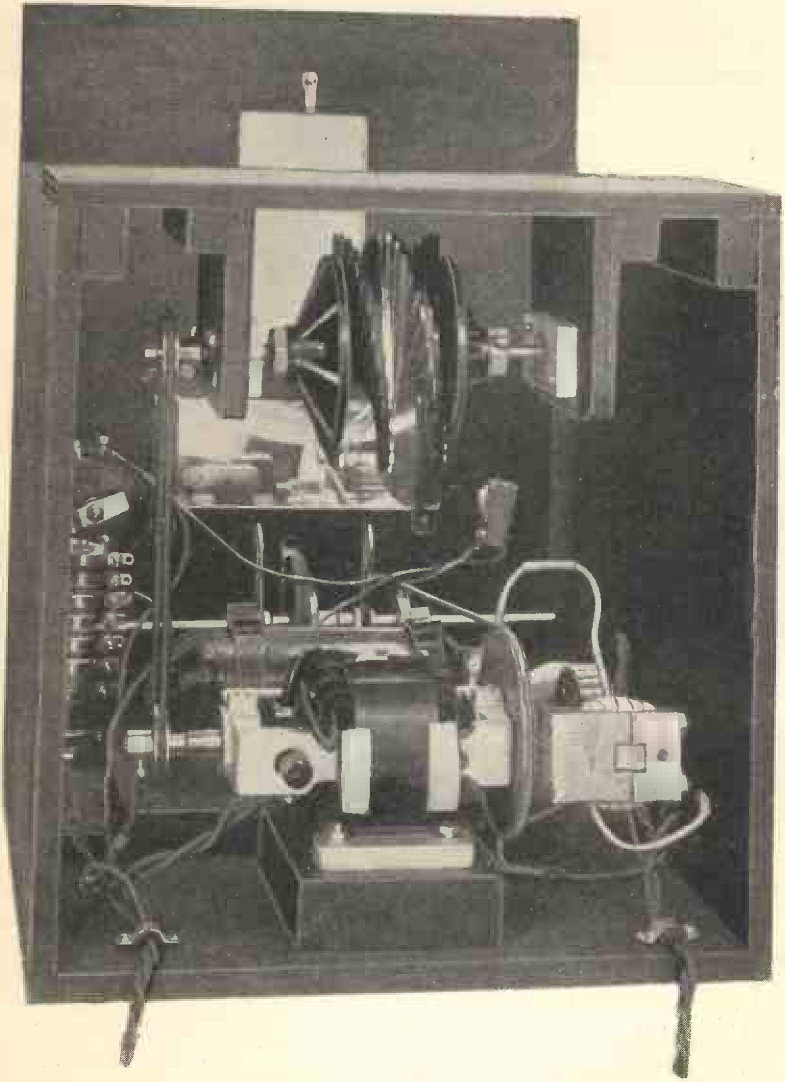
ACTORS AND PART OF THE "SCENERY" USED IN THE FIRST TELEVISION PLAY. THE INHERENT LIMITATIONS OF THE EARLY LOW DEFINITION SYSTEM DEMANDED GREAT INGENUITY IN THE CREATION OF MAKE-UP AND BACKGROUNDS

THE SIMPLEST FORM OF VIEWER



THE SIMPLICITY OF A LOW DEFINITION VIEWER IS VERY CLEARLY TO BE SEEN IN THIS PHOTO. THE PRINCIPAL PARTS ARE AN ADJUSTING RESISTANCE, DRIVING MOTOR, SCANNING DISC, NEON LAMP. THERE IS A SIMPLE MAGNIFYING LENS IN ORDER TO ENLARGE THE PICTURE

Plate 13



A COMPLETE MIRROR-SCREW VIEWER. THE SYNCHRONISER CAN PLAINLY BE SEEN ON THE RIGHT OF THE DRIVING MOTOR

Plate 14

beam of light through a series of small photographic pictures on a cinematographic film. If you take up a length of cinematographic film in your hand and examine it by holding it up to the light, it appears that all the pictures on it are pretty much the same (Fig. 20). In fact, however, each picture differs slightly from the one next to it. The camera with which the pictures are taken is exposed for a very short exposure at separate intervals of time, the usual rate being 24 pictures per second. Thus a photograph is taken at a certain instant with an exposure of perhaps 1/48th of a second; then the shutter of the camera closes, the film moves on to the next position, the shutter opens and another exposure is made; the shutter closes, the film moves on to the next position, then another exposure, and so on, so that what the camera sees is a series of separate and distinct views of the moving scene taken, however, with very short intervals of time between them.

THE CINE PRINCIPLE

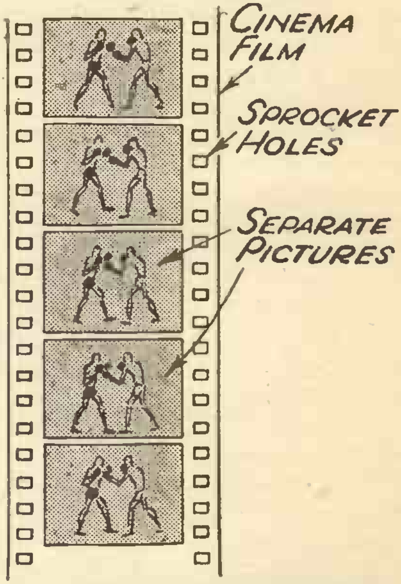


Fig. 20—A section of ordinary cinema film. In practice the successive pictures differ ever so slightly from one another and the difference is not usually noticeable on a short length of film. The separate pictures are projected in rapid succession and merge into a continuous moving effect due to persistence of vision in the eye

When the film is projected on the screen in the cinema theatre the shutter opens and allows the light to pass through, thus showing a *stationary* picture for a very small fraction of a second; the shutter then closes, the film moves on to the next position, the shutter opens and the next picture is shown in a stationary position upon the screen, and so on. Thus the successive pictures which have been taken at intervals of 1/24th of a second by the movie camera are projected at the same intervals of time, that is 1/24th of a second, on to the screen in the cinema theatre (Fig. 21).

A Magic Lantern Speeded Up. The important point to note, however, is that whilst it is actually being projected on the screen the picture is stationary; it is in every sense of the word a "still" picture. All that the projector is doing is to throw a series of still cinematograph pictures, precisely similar to those thrown by an old-fashioned magic lantern. The only difference between the movie pictures and the magic lantern pictures is that the movie pictures follow each other in such rapid succession that the eye is deceived and the impression of one picture has not yet died out from the retina before the impression of the next succeeding picture comes on, so that the observer gets the idea that there is a continuous and connected movement taking place on the screen. It may come as a shock to those of you who are film fans to be told that the modern cinematograph show is nothing more or less than a magic lantern show speeded up—but that is the fact.

THE SCREEN GOES DARK

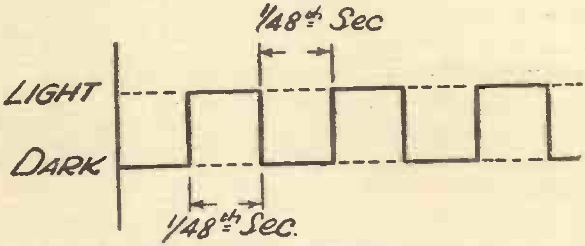


Fig. 21—This diagram shows roughly the way in which the cinematograph screen is "full light" for about 1/48th of a second, then dark for 1/48th of a second, then light and so on. The eye does not see the separate flashes, as these merge together

We have said that the usual rate of projection of cinematograph pictures to-day is 24 pictures (or "frames," as they are called) per second. This rate of succession of pictures gives a fairly good impression of continuity and does not seriously inconvenience the eye. It is obvious that the more pictures per second that are used, the greater the "footage" of film which passes through the projector for a given time of performance and therefore it is to the interest of film producers to use as small a number of pictures per second as possible. In the early days of cinematography the standard rate of projection used to be 16 pictures per second, and even at this slow rate the picture is seen as a continuously moving one. Some people, however, at this rate of projection, begin to have a sense of flicker and find a certain amount of discomfort in looking at the pictures for any length of time. A great deal of investigation has been carried out and it has been found impracticable to reduce the projection rate much below 16 pictures per second. Actually 12 pictures per second will "fuse" together and give the impression of continuity but at that slow rate they are liable to become very uncomfortable to watch.

"Flicker." We have used the term "flicker," and referred to the discomfort experienced by the eye in looking at pictures that do not follow one another sufficiently rapidly. Let us start at the opposite end of the scale with a " picture frequency " of one picture per second and gradually increase, so that we can study this effect more closely. We then find that at the rate of 1, 2, 3 or 4 pictures per second each picture is seen quite separately and definitely as a " still " picture. As the rate gets up to 5, 6, or 7 per second the pictures are still seen as separate ones, but the discomfort of the successive illuminations or flashes in the eye increases rapidly and when it gets up to about 10 per second the discomfort is acute ; most people find it impossible to bear intermittent illumination in the eye at the rate of about 10 per second. In scientific parlance, we may say that the flicker becomes most painful when it reaches a frequency of about 10 per second. After this rate is passed the discomfort begins to decrease and instead of seeing separate pictures (with discomfort) the eye begins to lose both the discomfort and the " separateness " and the pictures begin to fuse themselves together ; here

SENSATION OF FLICKER

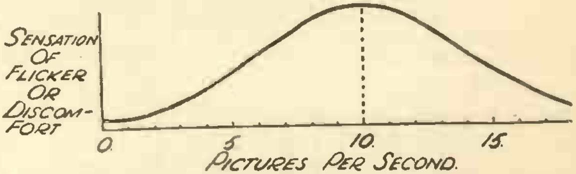


Fig. 23—Curve indicating the way in which the sensation of flicker or discomfort increases as the number of pictures per second increases, and reaches a maximum at about 10 per second, after which the sensation of flicker begins to disappear and the pictures merge together

A CAUSE OF DISCOMFORT

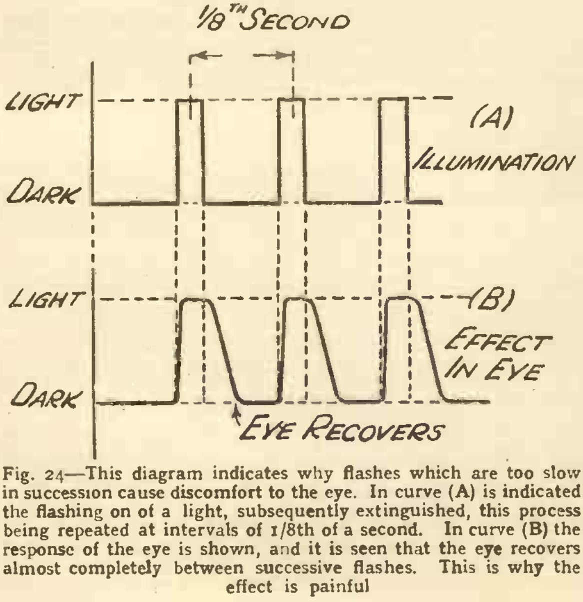


Fig. 24—This diagram indicates why flashes which are too slow in succession cause discomfort to the eye. In curve (A) is indicated the flashing on of a light, subsequently extinguished, this process being repeated at intervals of 1/8th of a second. In curve (B) the response of the eye is shown, and it is seen that the eye recovers almost completely between successive flashes. This is why the effect is painful

the impression of continuity begins to come in (Fig. 23).

Picture Frequency. If we assume that the persistence of vision lasts for about 1/10th of a second, we see that when the interval between successive illuminations is a little more than 1/10th of a second the eye is receiving separate excitations with just time to recover between them, and this proves to be very uncomfortable (Fig. 24). If, however, the interval between successive illuminations is considerably less than 1/10th of a second, the eye has hardly begun to recover from the stimulus due to the first illumination when the second illumination arrives, and so the retina is kept in a state of more or less continuous stimulation: this turns out to be much less uncomfortable.

OBTAINING A SMOOTHER EFFECT

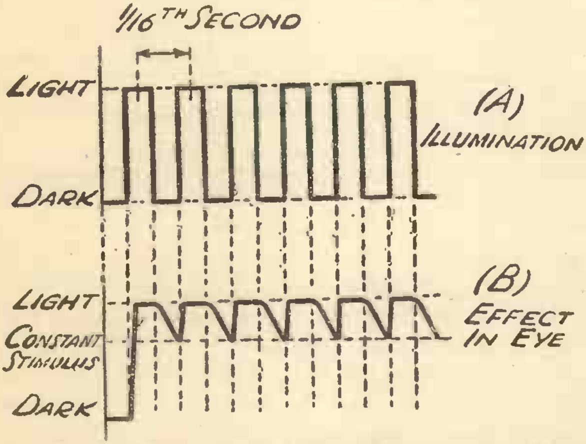


Fig. 25—This figure is similar to the previous one, but the flashes of illumination follow one another at intervals of 1/16th of a second. In curve (B) it is seen that the stimulus of the eye has not had time to die down appreciably before the next flash comes, and so the eye is kept constantly stimulated and the uncomfortable sensation is largely avoided

The greater the rapidity of succession of the pictures—the "picture frequency" (after about 16 per second)—the less the sense of "flicker" and the more comfortable the pictures become to look at (Fig. 25).

Now let us turn to the use of persistence of vision in the reception of televised pictures. We have already indicated that we rely upon this property of the eye for fusing together or building up the different light-spots, produced by the scanning spot as it flies over the receiving screen, into a complete picture. If the scanning spot just traced over the entire picture once and then stopped, we should be left with the impression of having seen a whole picture but for a very short space of time. In order to keep the picture continuously in view it is necessary for the scanning spot to keep on tracing out the entire picture time after time; after having started at the top and traced out all the lines right down to the bottom it has to go back to the top again and repeat the whole process.

So you see, we depend upon persistence of vision to build up all the different light-spots into a complete picture, and then we depend upon persistence of vision still further to build up or fuse together all these successive pictures into a continuous moving effect. In the cinema we do at least start with complete pictures, and we rely upon "persistence" to fuse separate pictures together; but in television, we have to make up each picture from the light-spots before we get to the starting point of the cinema film.

Effect of Definition. Let us assume that the "definition" of a televised picture is 180 lines, and that the entire picture is repeated 12 times per second. Then, obviously the light-spot has to traverse 180 multiplied by 12, that is 2160 lines per second. In passing along each of these lines, the intensity of the light-spot may have to fluctuate at least 180 times—say 200. The fluctuations of the light-intensity may therefore take place at the rate of 2160 multiplied by 200, that is, roughly half-a-million-times per second. The photo-electric cell at the transmitting end must therefore be able to respond faithfully to a change of light-intensity falling on it in something of the order of one millionth of a second.

From all this you will see the desirability of keeping the number of pictures per second, the picture frequency, as low as possible. If we went up to 24 pictures per second, the variations in the intensity of the light falling on the photo-electric cell at the transmitter would take place with twice the former rapidity and everything would be correspondingly increased in difficulty. On the one hand, we have to keep the picture frequency high enough to avoid flicker and discomfort to the observer, whilst on the other hand we don't want to make the picture frequency any higher than we can possibly help, in view of the technical difficulties.

In the 30-line B.B.C. transmissions, the picture frequency is 12½ per second; at this frequency the discomfort is noticeable to most people. Even if this were increased to a picture frequency of 16 per second it would greatly improve matters. The Postmaster-General's Committee recommended that high definition broadcast television should be on the basis of 240 lines (or more) and the picture frequency of 25 pictures per second (or more).

Line Frequency. Whilst you see, from the foregoing considerations, that a high line-frequency and a high picture-frequency are very desirable from the observer's point of view, they increase greatly the technical difficulties. Further than this, there are greater difficulties in finding radio frequencies for the transmission of the necessary modulations, but that is a matter we need not go into here as it is dealt with more fully in another part of this volume.

We have said that persistence of vision in the eye is essential for seeing continuity of movement by successive pictures. It would seem that we can never hope to get away entirely from our dependence upon persistence of vision. At the same time, however, it has been found possible to aid the persistence effect in the eye by means of a somewhat similar persistence effect in the screen itself. Let us take a simple illustration.

Electric Signs. No doubt you have stood, at some time or other, watching one of those moving electric signs, which consist of an assembly of electric lamps on which letters and words are made to run across—the " electric newspaper," it is sometimes called. Probably you have an idea how it works. Anyway, it has certain similarities to a crude system of television, so is worth studying for a moment.

" Behind the scenes " is a system of moving electric contacts which operate different combinations of the lamps successively. For instance, suppose the letter " I " is to be sent across the screen. For this a vertical row of, say, 6 lamps is switched on ; as the contact-mechanism moves forward, the next adjacent vertical row of 6 lamps is switched on, the first row being at the same instant extinguished. Then the contact moves on, and the third vertical row of 6 lamps is switched on, the second row being switched off, and so on. The contact moves rapidly, so the change along the successive vertical rows of lamps takes place rapidly and as the lamps, on being switched off, do not " go out " instantly, there is a limit to the speed at which the letters can be sent across the screen. Probably you have noticed that as the letters go across they leave a kind of fiery tail or furry luminosity behind them. This is simply due to the fact that the lamps which have just been switched off (and are therefore theoretically " out ") are not quite " out," but just in the act of going out. In other words, there is a kind of " persistence " effect in the lamps (Fig. 22).

If another letter is chasing the first one across the screen, it must not be so near that it treads on the " tail " of the first one. This is one of the factors that puts a limit to the speed at which the letters can be run across. Obviously, for these electric signs, lamps are used that have very little " lag," that is, lamps that " go out " very quickly after being switched off.

This gives us a clue because, although the persistence in the case of the lamps is not wanted, if we could introduce a similar effect suitably in a television screen, it would be a good thing instead of a bad one.

Screen Persistence. Let us consider the fluorescent screen used in a cathode-ray tube for receiving the televised pictures, because we shall find that an effect of this kind is exhibited by such screens and may be very useful.

AN ELECTRIC SIGN IN ACTION

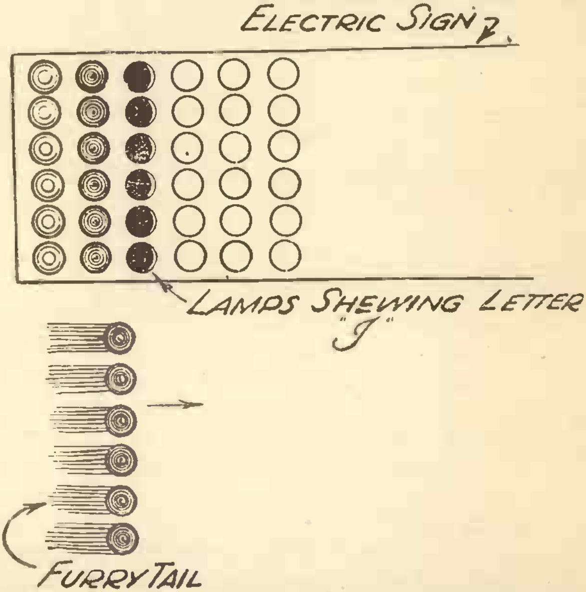


Fig. 22—The third vertical row of lamps are " full on," showing the letter " I," whilst the second row of lamps are switched off and are just losing their brightness, the first row of lamps having almost completely ceased to glow. In the lower part of the Figure is shown the impression in the eye, that of the furry tail to the letters as they run across the bank of lamps. The arrow indicates the direction of travel of the letters

Fluorescent Screens. The screen consists of a fine coating of material—of which barium platino-cyanide is a familiar example—which becomes luminous when bombarded by a stream of high-speed electrons. The stream of electrons in the cathode tube hits this screen and a bright spot appears at the point where the cathode beam strikes it. If the cathode beam, instead of remaining stationary, is made to fly over the fluorescent screen and " scan " it in the way already described, and if the beam at the same time varies so as to vary the brightness of the spot, we will get a picture produced on the fluorescent screen. Now obviously we want the commencing part of the picture to remain visible until the end part of the picture has been completed. Hitherto in our explanations we have supposed that the duty of keeping the picture in view falls entirely on the persistence of vision effect in the eye. But if the fluorescent material itself exhibits a certain lag, that is, if it continues to glow for a short interval after the excitation due to the impact of the cathode beam has ceased, then it will of itself provide this persistence effect and to that extent assist the eye.

Phosphorescence. The emission of light from a substance of this kind when actually under excitation is called " fluorescence," whilst the continued emission of light after the exciting cause has been removed is called " phosphorescence." In practice it is probable that every fluorescent substance exhibits a certain amount of phosphorescence, that is to say, that the activity takes a certain time to die away after the exciting cause has ceased to operate. Different substances, however, show very great variations in this phosphorescent " lag " and experiments are now being made in order to find out how to produce just the right amount of persistence in the screen itself to help the eye and reduce flicker, without causing overlapping and blurring. Some experts believe that there is an important field for development in the direction of screen phosphorescence.

We have now seen how a single television picture is built up by a spot of light, the brightness of which varies appropriately as it traces out the picture in a series of lines, and how this system of lines is made to appear as a single picture, owing to persistence of vision. We have also seen how the individual pictures are repeated in rapid succession so as to give the impression of continuous movement, again relying upon persistence of vision. The successive pictures must follow one another at not less than a certain minimum rate, otherwise we get the uncomfortable sensation of flicker. Finally, we have seen how the persistence of vision effect in the retina of the eye can be assisted by utilising a similar persistence in the actual material of the screen on which the television pictures are received.

Brightness of the Received Pictures. Before concluding this chapter, it will be useful to say something about the actual brightness of the pictures received, as this is not the least of the many questions which confront the television experimenter. In fact, one of the main problems in television to-day is to get sufficient light into the received picture : in view of what has been said in the foregoing you will easily appreciate this difficulty. The spot of light which traces out the picture may be intrinsically bright, but it has to fly over the picture at such a rate that it only rests on any particular spot for an extremely short space of time. You will remember we calculated that if the spot traced a picture of 180 lines at a picture frequency of 12 pictures per second, it would only rest on a spot of the screen equal in area to the scanning spot itself for a time of something like 2½ millionths of a second.

It is sometimes stated that the brightness of illumination of the picture is equal to the brightness of the illumination of the scanning spot divided by the area of the picture. This is a simple way of approaching the question of the illumination, and at first sight you might think that the intensity would be simply the total light falling on the picture (that is, the total light in the scanning beam) divided by the area of the picture, since the available light has to be spread out over the whole picture area.

Owing to various physiological and psychological effects, however, the brightness cannot be arrived at in this simple way. The brightness is not the same as though we took the total amount of light in the scanning beam and distributed it over the whole of the picture area. This is another of those fortunate accidents which help to simplify television, or rather to render it less difficult than it would otherwise be. Nevertheless, the fact remains that the received television picture is very lacking in brightness as compared, for example, with a good home cinematograph picture, and a great deal still remains to be done in this direction.

Light and Shade. Then there is the question of light and shade, or " contrast," between the different parts of the received picture. A change in the brightness of any part of the picture is judged by the eye, not by the actual magnitude of the change, but by the magnitude in relation to the original brightness. This means that the brightness of a bright spot has to increase more than the brightness of a faint spot for the eye to conclude that there has been the same degree of change in each of them, and is an informal expression of an important law known as Fechner's Law. We need not go into this further just now, however, as it will arise again later on.

J. H. T. R

Chapter 7

TELEVISION TRANSMISSION

AN ACCIDENTAL DISCOVERY—PHOTO-ELECTRIC CELLS—CHANGING LIGHT INTO ELECTRICAL VARIATIONS—DISC SCANNING—A SIMPLE EXPERIMENT—FLOODLIGHT AND SPOTLIGHT SCANNING—THE MIRROR DRUM—FARNSWORTH'S ELECTRON CAMERA — THE ELECTRON MULTIPLIER—ZWORYKIN'S ICONOSCOPE — THE INTERMEDIATE FILM PROCESS—SYNCHRONISATION—SEPARATE SCANNING TRANSMISSIONS — VELOCITY AND INTENSITY MODULATION—INTERLACED SCANNING.

Fifty or so years ago an elderly scientist bending over a bench in his laboratory noticed that something happened to his apparatus when a bright light shined upon it. Although he did not live long enough to see it, this accidental discovery ultimately resulted in the development of the modern photo-electric cell, which has hundreds of valuable uses additionally to being the keystone of television transmission.

The photo-electric cell has the power to produce an electrical pattern of light variations. Shining a bright light on to a photo-electric cell connected to suitable amplifiers causes an electrical current to flow, the strength of which will vary exactly and immediately in accordance with any changes in the brightness of the light. Take the light farther away and the current falls; bring it nearer and it rises.

The effect which Prof. Hertz noticed in 1888 was that when light was shone on to a piece of zinc, which he was using for something quite different, it caused the metal to emit particles of electricity. Some say that Hertz didn't get as far in his observations as to arrive at this final conclusion, and that all he was responsible for was the pointing to an-at-first-unexplainable phenomenon. But we would like to see this respected scientist given generous credit for his valuable pioneering.

Photo-electric Cells. It was subsequently discovered that any metallic substance has the power to throw off electrical particles (electrons) when subjected to the influence of light rays. But some metals are very much more " light sensitive " than others. Also they all vary in their sensitivity to different kinds of light. For example, zinc, the metal which we might almost call the father of photo-electrical phenomena in view of Prof. Hertz's initial discovery, is among the less sensitive, and, moreover, it reacts appreciably only to the invisible ultra-violet rays and not to the rays which constitute the visible part of the light spectrum.

The alkali metals, potassium, rubidium, caesium, strontium, lithium, sodium and barium, give the best results with visible light. And of these it is found that caesium, a silver-like metal, is the most sensitive. By that we mean it throws off the most electrons (particles of negative electricity) for a given amount of light. Therefore, caesium is the substance most widely used in modern photo-electric cells.

At one time they used to employ a solid mass of the material, but it was eventually learned that the best results were achieved with an extremely thin layer backed with silver, no more, in fact, than a film of it much thinner than a cigarette paper.

Incidentally, the sensitivity of a caesium photo-electric cell increases at the red end of the spectrum, and so it is especially suited to artificial lighting.

The caesium-silver combination only forms one part of the complete cell. It is known as the " cathode." There is also the anode, a simple metal structure such as a loop of wire or a piece of wire gauze, and the two are sealed into a glass bulb from which the air has been extracted. In the place of air there is a certain amount of inert gas, generally argon in the more sensitive gas-filled cells.

The cell is connected up so that there is a positive voltage on the anode in order to attract the electrons emitted from the cathode. On their way over, however, they encounter the atoms of the gas which has been introduced into the bulb. If the attracting voltage on the anode is fairly low all that happens is that the electrons jostle through, bumping into the gas atoms and bouncing off them again. But if the voltage is increased, the speed of the electrons is increased,

OBSERVING ITS ACTION

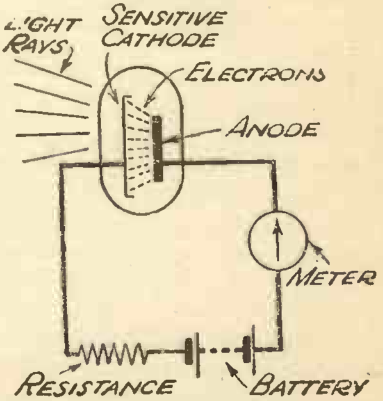


Fig. 26—A photo-cell connected to a meter in order that its action can be observed

and they strike the gas atoms with greater force and knock electrons off them. These electrons add to the volume of those travelling to the anode. Increase the attracting voltage still more and the energy of the electrons will increase until they begin to bounce backwards and forwards from gas atoms to the cathode and knock further electrons off the latter before finally completing their journeys to the anode. And so the volume of electrons can be increased and increased by making the anode voltage greater and greater. But there is a limit beyond which the effect cannot be taken.

You must remember that an electron is a particle of electricity. An electrical current is merely a flow of electrons. Now, when light rays of a given intensity strike the cathode of the photo-electric cell a certain proportionate number of electrons is emitted. But by introducing the gas and setting the anode at a certain voltage, there is a multiplication of the stream of electrons. A greater current is caused to flow, the cell is made even more sensitive.

The snag is that while the gas-filled cell is more sensitive than the vacuum type, it is less stable in action and requires compensation in its associated circuit for lag, particularly at the higher frequencies.

Changing Light into Electrical Variations. If a photo-electric cell is connected up in the manner shown in Fig. 26 its action can be closely observed by means of the meter. The purpose of the resistance is to limit the current flow, for if it were to be allowed to rise to too great an extent the cell would be damaged.

A PHOTO-CELL CIRCUIT

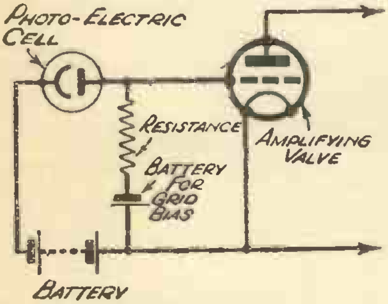


Fig. 27—Showing how the photo-electric cell is connected to an amplifying valve

The meter measures the amount of current flowing in the simple circuit, the voltage of the battery being such that the cell works sensitively but well within its safety limits.

It would be noticed that a certain amount of current would flow even if all light were excluded from the cell. This current is known as the "dark current," for an obvious reason. But it is a very small current in the type normally used.

You will see in Fig. 27 how a cell can be connected to an amplifier circuit. The current variations occurring through the resistance produce changes of voltage across the ends of this, which are communicated to the grid of the amplifying valve. The grid bias battery has the quite normal task of keeping the valve biased in just the same way as is done in the case of an ordinary L.F. valve used in a radio set.

With an efficient means of transforming light variations into changing electrical energy to hand in the photo-electrical cell, half, or more than half, of the difficulties of television transmission are solved. What requires to be done is to break the picture up into light points as explained in preceding chapters.

Disc Scanning. The simplest method is to use a scanning disc. The action of a scanning disc is illustrated by Fig. 28. The disc shown has eight small square holes in it, arranged spirally. Imagine a picture placed behind this disc as indicated by the dotted lines. You are facing the disc, and all you can see of the picture is a tiny square of it through one of the holes. If the disc is slowly rotated in a clockwise direction you will first see succeeding patches of the picture running in a slightly curved line at the bottom. As soon as the first hole leaves the picture the second one starts to traverse a strip slightly higher up. This is followed by the third hole covering a third strip, and so on until you get to the eighth hole which runs across the top and final strip. Then the first hole starts again to run across the bottom strip, and it is actually shown as doing this in the sketch. The whole picture has been scanned once. If the disc were rotated very rapidly you would be able to see the whole of the picture because of the persistence of vision that is a quality of the human eye.

THE "NIPKOW" DISC

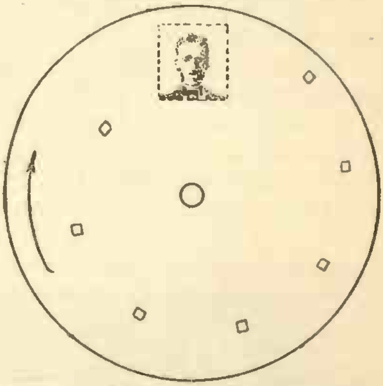


Fig. 28—An illustration of the principle of the scanning disc. This scheme was invented by Nipkow in the latter part of the nineteenth century

A Simple Experiment. There is an interesting little experiment which you can make that will illustrate the effect. Take a piece of cardboard of any convenient size of or about the dimensions of a postcard. In fact, a postcard would prove quite suitable. In the centre make a pin-hole. Now look at any brightly illuminated scene through the pin-hole, using only the one eye and closing the other. The kind of scene we have in mind is the view obtainable through a window into a sunlit street or garden.

While you keep the card stationary all that you will see will be one tiny but brightly lit portion of the scene. But if you move the card backwards and forwards an inch or two with a rapid action you will find that you will be able to see a strip of the scene quite clearly. You are using persistence of vision and are scanning a strip of a picture. If the movement of the card could be speeded up several times and moved backwards and forwards over successive strips of the scene so that the whole of it was covered in a continuous series of complete scans, then you would see the whole view, although the pinhole would have to be kept fairly close to the eye.

However, although this little experiment will give you something of a practical idea of the principle of scanning, don't follow it up too far. With the vague suggestion of the general idea in mind, let us return to the eight-hole scanning disc which we have been discussing.

Scanning with a disc having only eight holes would not provide good television transmission. The photo-electric cell reacts to different intensities of light ; it doesn't by itself analyse picture detail. If the whole of a picture were focused on it it would merely treat it as bright or dull light, not as an intricate pattern of light shades and contrasts. You saw a little patch of picture through one of those square holes in the eight-hole disc, and that is, too, what is to be seen through a pin-hole in a card : the photo-electric cell would " see " nothing but successive squares of different light values. Therefore, if pictures scanned only in eight strips or lines were transmitted, " lookers " would get nothing but extremely crude results on the style of Fig. 29. The new television technique does not reckon that anything under 180 lines or so is good enough. For 180-line scanning clearly, a disc having 180 small square holes in it is needed. Perhaps we should have said exceedingly small, because the dimensions of each hole must be no greater than the thickness of a " line," and the picture is divided into 180 lines.

VERY LOW DEFINITION!

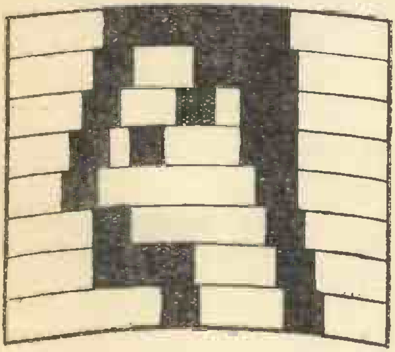


Fig. 29—The kind of effect that would occur if a human face were scanned in only eight lines

Floodlight and Spotlight Scanning. There are two ways in which this kind of scanning can be applied. The first is known as "floodlight" scanning (Fig. 30). The person or scene to be televised is brightly illuminated by means of floodlights, and by means of a lens the picture is sharply focused on to the scanning disc so that it occupies a position on it suited to the arrangement of the scanning holes—like we arranged the picture behind the disc in Fig. 28, so that the holes would completely scan it. Light passes to the photo-electric cell through one hole of the rotating disc at a time, and therefore the picture is transformed into a series of varying light values, which in their turn are changed into electrical fluctuations by the photo-electric cell.

USING REFLECTED LIGHT

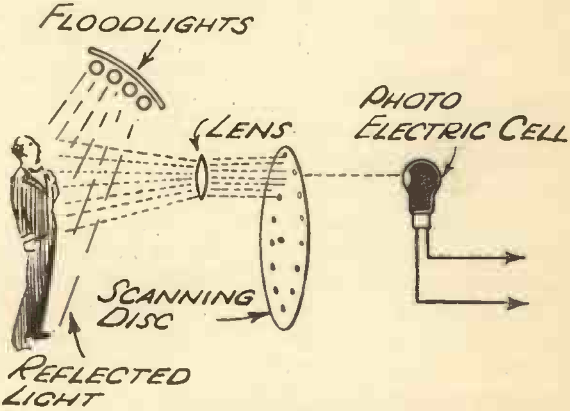


Fig. 30—In the "floodlight" method of scanning the whole of the objects or scene to be televised must be bathed in light

The disadvantage of this method is that the subjects to be televised have to be bathed in very brilliant light. In the early days of television, when the photo-electric cells were less sensitive than they are now, so much light had to be used that the televised actors were nearly boiled by the heat of it! Just as were the first cinema stars. Later the spot-light system of scanning was introduced, Fig 31. In this a powerful light

SPOTLIGHT SCANNING

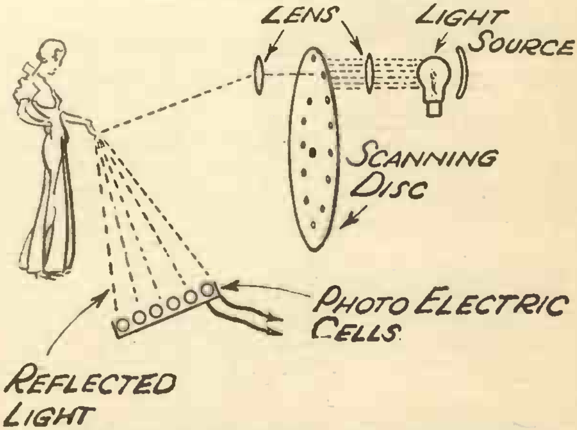


Fig. 31—A tiny pencil of light flashes over the subject being televised

is focused on the back of the scanning disc in such a way that it can get through only one hole at a time. Again, refer to Fig. 28 and in your mind replace the picture by a rectangle of light.

The spot of light is thrown on to the scene to be televised and is reflected from this in all directions, or rather, at all angles to the front of it. Banks of photo-electric cells are arranged to pick up this reflected light, which will vary in intensity as with different parts of the scene. It is fascinating to watch an artiste being scanned by spot-light methods. You know that what is actually happening is that one tiny pencil of light is being flashed over the scene and that, were the scanning disc to be stopped, all that you would see would be a mere pin's-head of light relieving an otherwise complete black-out. And yet it seems as if the subject is illuminated by a steady floodlighting, though it is rather dim.

We are now in a position to summarise the whole process of the transmission of television. Fig. 32 will help to put it all in its right perspective. A powerful light is focused on to a revolving scanning disc, and the speed of this is kept absolutely constant at a rate which enables the complete picture to be scanned twenty-five times per second. There is one complete scanning for each single revolution of the disc so that it revolves twenty-five times per second.

The varying light intensities reflected from the picture reach a bank of photo-electric cells; in some cases there may be more than one group of them, but as they are all electrically joined together they all act in unison as one large cell of several sections, as it were. The fluctuations of electrical energy developed by the cells are passed to an amplifier for magnification from which they go to the control desk or panel on which there are meters and

THE TELEVISION TRANSMITTING CHAIN

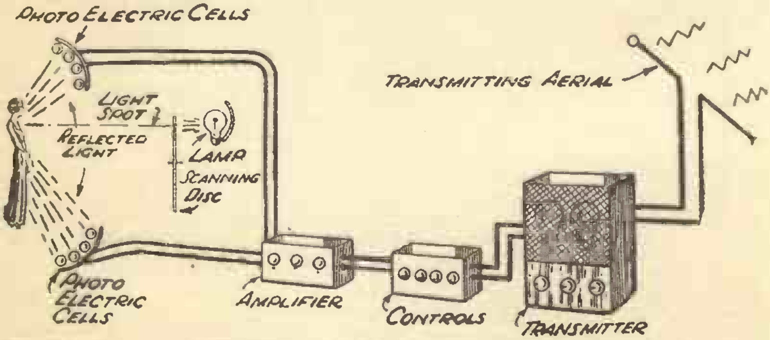


Fig. 32—This sketch summarises all the processes of a spot-light, disc-scanning television transmitting system

adjustment knobs under the observation and care of the engineers. Their next port of call is the ultra-short wave radio transmitter, and this is connected to special ultra-short wave aerial system which flings the pictures into space in the form of wireless waves.

The Mirror Drum. The disc is a mechanical form of scanning, and there is an alternative, which has been widely used, known as the mirror drum (Fig 33). Instead of the disc with holes in it a drum having mirrors arranged around its edge is employed. There are exactly as many mirrors as there are holes in a disc for the equivalent definition of scanning. Thus for 180-line work there would need to be 180 mirrors. A light is focused on to the drum so that it strikes only one mirror. Each successive mirror is tilted a little further than the last one and so, as the drum revolves, spotlight scanning is accomplished. It will be appreciated that for 180-line scanning the design and construction of a mirror drum is an optical task of some magnitude.

MIRROR DRUM SCANNING

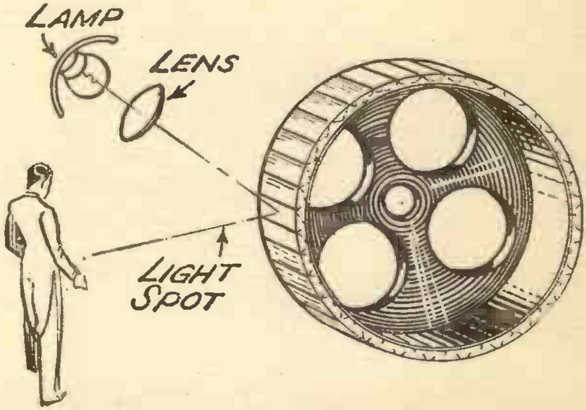


Fig. 33—Each successive mirror is tilted slightly more than the one which precedes it, so that the light-spot is reflected over successive strips of the picture. The mirror is shown here vertically scanning

There are several other mechanical methods of scanning: for example, there is the mirror-screw and, again, the oscillating mirror, and the principles of these are dealt with in the chapter covering mechanical systems of television picture reception. They have been used in transmission, but not to any great extent. The disc and mirror drum are the only methods of mechanical scanning to be found in modern television transmission. It is more than probable that these will in due course be displaced by electrical methods. The disc or drum is perfectly satisfactory for definitions up to two hundred and forty lines or so, but beyond that transmitting engineers believe that they will not be used. On several scores it would seem most probable that future development will tend to be confined to the electrical systems. There are two of these at present either in use or being experimentally tested.

Farnsworth's Electron Camera. The Electron Camera is attributed to Farnsworth, an American inventor, though the principles on which it depends for its functioning were known for some years previously. The Electron Camera employs a photo-electric cathode of similar properties to that found in the photo-electric cell (Fig 34). The picture to be televised is focused on to this cathode which emits electrons (particles of negative electricity), and which vary in number from point to point as with variations of the light values of the picture. By means of carefully arranged electrical " guides " the electrons are made to leave the cathode in straight lines, keeping a uniform pattern. Thus, if you took a cross-section of the whole mass of the cloud of electrons at any point away from the anode within the glass bulb, you would find that it represented an electron image of the picture just like the

A SYSTEM OF ELECTRIC SCANNING

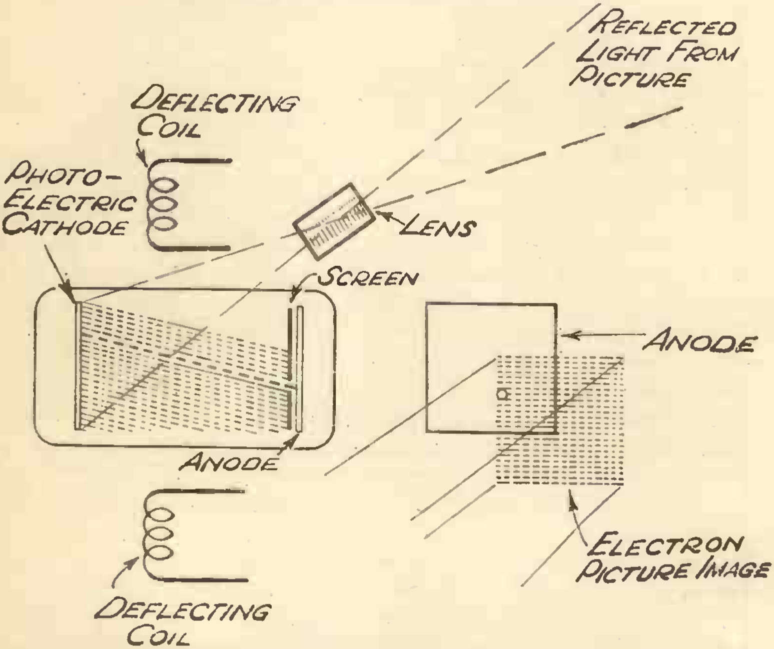


Fig. 34—Illustrating the principle of Farnsworth's Electron Camera. On the right is shown how the electron image is moved in a scanning action relative to a small aperture which screens the anode

cross-section of the rays leaving a cinema projector forms a light-ray image of the picture, although it could not be seen as such in its entirety unless it were first made to strike a screen.

The cathode of the Electron Camera is situated at the one end of a glass bulb from which the air has been extracted, and at the other end is the anode, and this is covered by a shielding screen in which there is a tiny hole.

As we have said when the picture is focused on the cathode, electrons are released which fly towards the anode in a definitely regular formation—if they were light rays and the screen were an ordinary reflecting screen, you would see the picture on it. Situated outside the bulb are " deflecting coils " which magnetically influence the electrons. Currents of electricity are passed through the coils so that the whole-electron image is moved in a scanning motion, each part of the electron image in turn coming opposite the tiny hole in the screen. You can visualise the effect more clearly perhaps if you think of the electron image as stationary and the tiny hole scanning it, though it is exactly the reverse that happens. Through the tiny hole a few electrons pass, the exact number depending upon the light intensity represented by that part of the picture.

Now, you know that an electric current is a flow of electrons, so if these electrons which escape through the tiny hole are communicated to an external circuit the process of changing varying light into fluctuating electricity is complete.

It should be mentioned, however, that the resulting currents are extremely small and considerable subsequent amplification is required.

It was for this purpose that Farnsworth developed his " Electron Multiplier," which is claimed to give up to a million-fold amplification and over. The principle on which this works is similar to a principle we have already become acquainted with in connection with the photo-electric cell. That is, the releasing of electrons by bombardment. In the Farnsworth's Multiplier the principle is considerably extended. By applying suitable voltages to the anodes of a device rather like a double-ended photo-electric cell, the initially emitted electrons are made to release large secondary and even tertiary emissions, the process being controlled by means of the small currents arriving from the Electron Camera just as the small voltages fed into a valve used in a radio set control the considerably higher voltages occurring in the output circuit.

The Electron Multiplier. The normal types of valve amplifier possess snags. Owing to what is known as the " Shot " effect there is a practical limit to the amount of amplification which can be given to anything. The effect is the development of " noises " in a valve. These noises are very faint, so faint as to be negligible in any ordinary single valve amplifier. But when valve after valve has to be used in order to build up considerable amplification, then the noises develop as an interfering background like the harsh rustling of wind through the autumn trees. Obviously, if the initial energy to be amplified is as weak as the " background noise " in the first valve, the background noise being amplified as much in succeeding valves and even added to by their own backgrounds, the interference finally will completely ruin the process.

We have referred to " noise " because practically all readers will possess radio sets and will be able to comprehend the part which inherent background can play in spoiling results. It will be appreciated, therefore, that it isn't " noise " until a loudspeaker is introduced to transform the electrical fluctuations into sound waves. This isn't done with the photo-electric cell used for television transmission. The electrical fluctuations remain as such through the transmitting chain and are made to create radio waves which in their turn are caused to generate electrical variations in a receiving equipment designed to build up the picture.

COMBINED IN ONE UNIT

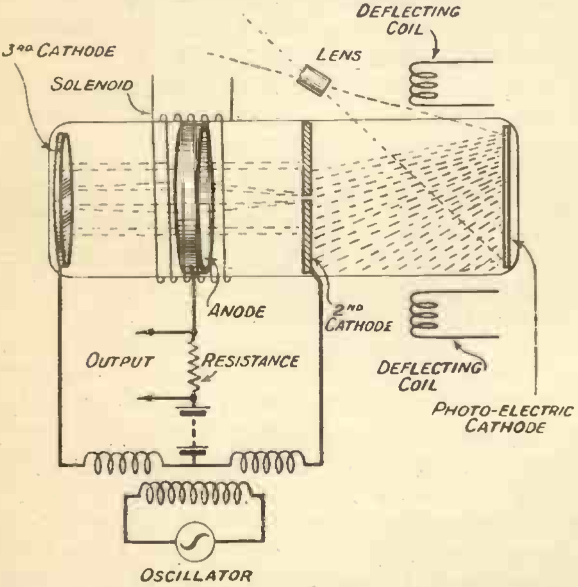


Fig. 35—Farnsworth's Electron Camera or Dissector and his Electron Multiplier combined in the one unit. This system is being used in this country by Baird Television Ltd.

The parasitic currents, to give the "Shot Effect" a more correctly descriptive name, render it necessary that the photo-electric cell or the electrical scanner should be able to develop a certain minimum current if clean television transmission is to be possible with the aid of valve amplifiers. The Farnsworth Multiplier was devised more or less as a direct outcome of the fact that the Farnsworth Electron Camera has a very limited output, thus rendering it practically impossible to use a valve amplifier.

An accompanying illustration (Fig. 35) shows how an Electron Multiplier and the Farnsworth Electron Camera (or Dissector as it is often styled) can be built into one compact unit.

The anode of the " Dissector " is replaced by a second cathode which, of course, has the small hole in it. The anode is for the purpose of adding velocity to the electrons which get through that tiny hole in the second cathode. It is fashioned in the shape of a ring and the tendency for the electrons to fly to it is reduced by the provision round it of a solenoid which creates a strong magnetic field.

ANOTHER SYSTEM OF ELECTRIC SCANNING

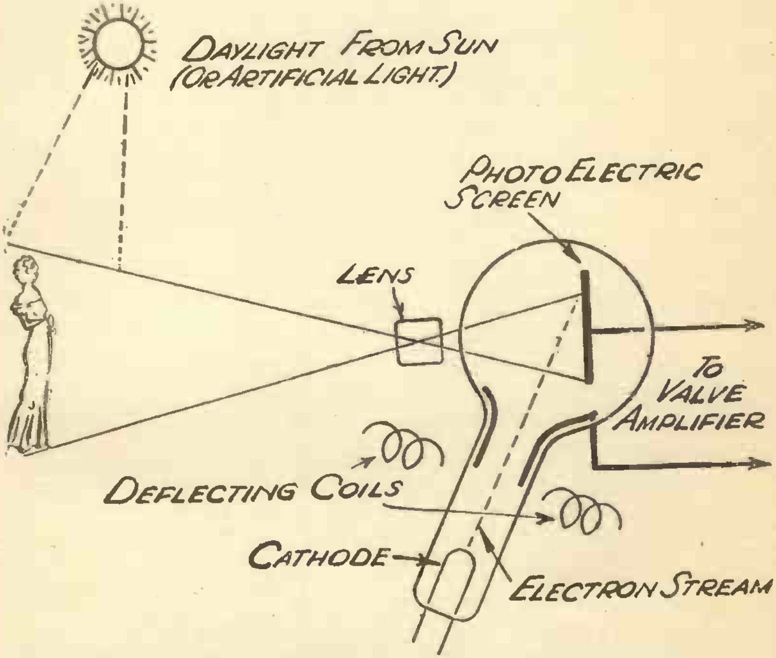


Fig. 36—Zworykin's Iconoscope, which is the system of electrical scanning employed by the Marconi-E.M.I. Television Co.

So the electrons fly through and strike the third cathode, which is made of some such substance as caesium. A number of electrons is knocked off this, and an alternating current being applied to the second and third cathodes makes these electrons fly backwards and forwards between them, knocking off more and more electrons, for the second cathode, too, is of caesium or some similar highly emissive substance.

So the first few electrons which escaped into the Multiplier Section of the device through that tiny hole build up into a comparatively large stream which bounces backwards and forwards between the second and third cathode, growing bigger and bigger with each traverse of the Multiplier.

There are two ways in which the process can end. A periodic quenching frequency can be applied so that the amplification periodically ceases. Alternatively, there will eventually be a drift of the electrons to the anode which will conclude the cycle of amplification. This drift can be controlled by varying the intensity of the guiding magnetic field set up by the solenoid. If this is increased the drift is retarded. Also the alternating current applied to the anodes can be increased or reduced to vary the drift accordingly.

Thus it will be appreciated that the "Multiplier" is a flexible device.

Zworykin's Iconoscope. A method of electrical scanning which has given very good results, and is being developed very actively, is Zworykin's Iconoscope. This is illustrated in Figs. 36, 37 and 38. The Iconoscope is rather like a distinctively shaped cathode-ray tube. In fact, it has at its one end most of the essential elements of one of these devices. For this reason and to prevent the necessity of going over the same ground twice, we would advise readers to skip the following few paragraphs and return to them after they have read those chapters dealing with the Cathode-Ray Tube.

THOUSANDS OF CELLS

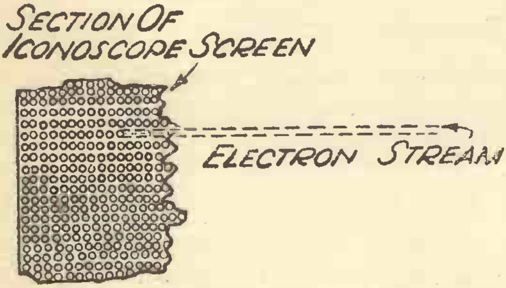


Fig. 37—The photo-electric screen of the Iconoscope consists of a compact mosaic of tiny photo-electric cells

The glass bulb of the Iconoscope is, as you can see if you examine the sketches, shaped rather similarly to a wine flagon, and it is something of the dimensions of one of these objects; at least, the type which graces the sideboard in a dining-room and not the huge ones seen in pantomimes! In the narrow end are a cathode and the anode and shields for the production of a thin scanning stream of electrons. But in place of the deflectors, deflecting coils are arranged externally.

At the other end is a screen composed of a mosaic of tiny photo-electric cells. There are tens of thousands of them, and they are made by depositing globules of caesium and silver on a sheet of mica. The mica is backed by a metal plate. The picture to be scanned is focused on to the screen, and each minute photo-electric cell has an electric charge developed in it proportional to the light which shines on it. As these little cells are separated from a metal plate by means of an insulating material (the mica backing), each is in effect a small condenser, so that you now have a mosaic comprising thousands of small condensers, each holding an electric charge which will vary as with the intensity of the light which reaches it. The mosaic is scanned by the electron stream. This has the effect of neutralising the charge of each cell as it reaches it. The voltage changes so created are communicated to the external circuit.

NEUTRALISING THEIR CHARGES

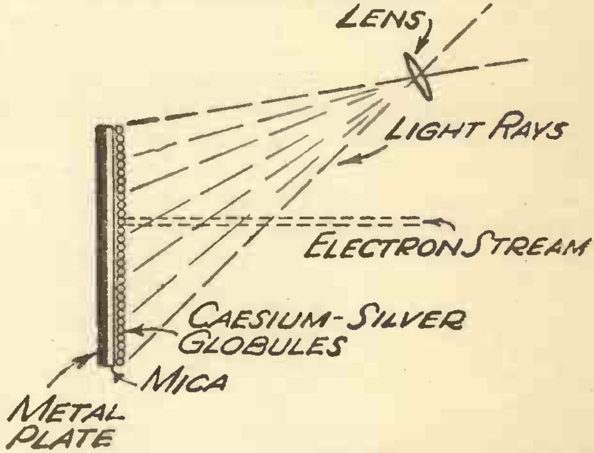


Fig. 38—The mosaic of cells is scanned by means of a stream of electrons which neutralises the charges of electricity formed in them by the light rays from the picture which is being televised

It should be noted that the one connection is provided by the metal plate and the other by a metallic lining to part of the bulb which acts as the electron "return." In other words, the electrons comprising the scanning stream return to the cathode via this metallic lining after they have accomplished their task. And in this way the circuit for setting up the potential variations is completed.

The Intermediate Film Process. The Iconoscope has been used successfully for televising both indoor and outdoor scenes, and its employment will doubtless prove capable of extension. At present, however, out-of-doors scenes are largely transmitted with the aid of the Intermediate Film Process. A talking film of the scene is first taken with an ordinary talkie camera, and when the film has been developed and fixed it is passed through a television transmitter and a " sound head " for taking off the sound. Rapid processing reduces the delay to a matter of minutes.

There are two applications of the idea. In the one the film is retained and this has the advantage that a permanent record is available of the event. In the other, a continuous belt of film is employed, the emulsion being washed off and renewed as it runs through the mechanism. In this system the film processing is still further speeded up so that the delay is reduced to about thirty seconds or even less than that.

ALL IN HALF A MINUTE!

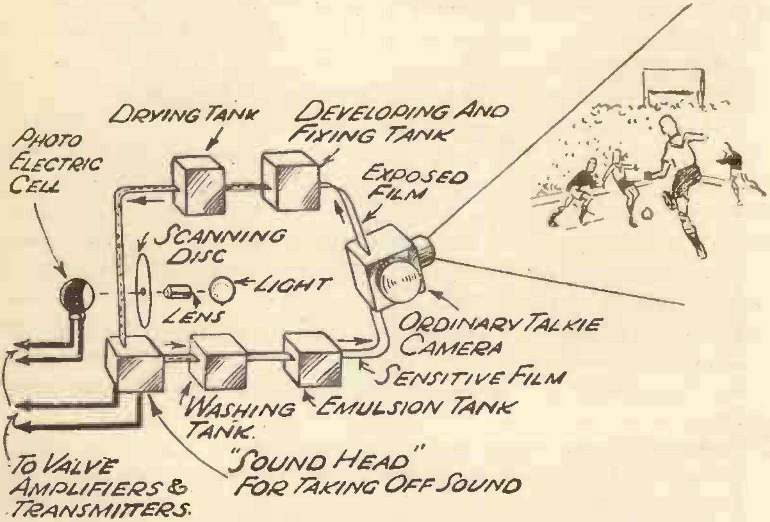


Fig. 39—In this Intermediate Film Process a continuous band of film is used. Only about 30 seconds delay is occasioned by the developing, fixing, and drying of the film after it has been exposed and before it is ready for televising

Fig. 39 clearly illustrates the method. The film passes through an Emulsion Tank which coats the clear celluloid with sensitive emulsion. It then goes to the camera and the pictures and the sound track are impressed upon it. The exposed film then reaches developing and fixing tanks. The developing solution is kept at a much higher temperature than is usually employed by even press photographers for the developing and fixing have to take place in a few seconds. The solution is heated by means of electrical heaters, and, needless to say, the film emulsion is of a special character for ordinary emulsions would melt in the nearly boiling solution.

There is only a slight washing, for the film is not intended for a long life. After drying, the film is scanned and the sound taken off by a quite normal sound-head, and for details of these processes we can refer you to a later chapter in this book.

Finally, the film traverses a washing tank which removes all the emulsion, pictures and sound track and all, leaving only clear celluloid. Then the whole chain of actions is begun again, in so far as that particular section of the celluloid strip is concerned, for while it was being developed and fixed the camera was at work taking other pictures, the scanning apparatus scanning pictures which had already been fixed and dried, and so on. It is, in fact, a completely continuous series of processes, and it is carried out by the one complete and fairly compact installation. "Fairly" complete and compact, you will note. It is sufficiently heavy to make its transport something of a problem in cases. In Berlin there is a van fitted up with Intermediate Film Process gear, and this van runs all about the city taking interesting shots, which are sent back to the transmitting station by means of an ultra-short wave radio link. But we have yet to see an outfit which could be transported by one or even two roving television camera men! Not that this is possible with any other system as yet. What can be done quite easily, however, is for a couple of men to collect talkie shots with a normal talkie equipment and rush these back to the transmitting station for quick processing and subsequent transmission by normal television methods.

Synchronisation. And now for synchronisation. It is useless to send out television transmissions unaccompanied by something which will enable the looker to ensure that his apparatus scans in step with the scanning of the transmitter.

There are several methods of ensuring this. One that has been used to a considerable extent is to introduce a black band along the one edge of the picture or scene to be televised. This results in an even distribution of electrical impulses that can be applied for synchronising the receiver. The drawback to this method is that black patches in the picture might confuse the synchronising apparatus. To overcome this, another system introduces an independently generated impulse which is much stronger than any of the impulses developed in the scanning of the picture.

Separate Scanning Transmissions. A further idea is to send scanning impulses out on a third wavelength, the other two being used for vision and sound. These scanning impulses are picked up by the looker on a separate set and, after suitable amplification, applied to the deflectors of his cathode-ray tube. Thus there is no synchronising to be done at all at the receiving end. As an extension of this principle, schemes have been suggested for combining scanning and vision transmissions on one wavelength, though it remains to be seen whether or not this is a practical proposition.

All the foregoing information regarding the transmission of television has been concerned with the general principle known as Intensity Modulation, This is simply explained. All that it means is that the strength of the electrical current variations, which are produced by the photo-electric cell and passed to the subsequent amplifiers and radio transmitter, correspond with the variations of light intensities which compose the picture.

For a black patch, no current ; a white patch, maximum current, and intermediate current strengths for intermediate degrees of lighting. These current fluctuations are applied to the radio transmitter in the same way as are the currents obtained from a microphone due to the rises and falls of volume in a musical note.

Velocity and Intensity Modulation. An alternative system, which has many possibilities, is known as Velocity Modulation. This necessitates the employment of a special electrical scanning process. The scanning is not an even movement of a light-spot or electron stream over the picture. The picture is covered in a series of strips as normally, but the speed of the scanning spot varies as with the intensity of the light of the picture. It passes quickest over dark or dimly illuminated patches and slowest over the brightest patches.

The scanning at the receiving end obeys a similar law. Clearly a point of light which flashes very quickly over, say, a quarter of an inch of the receiving screen will not look as bright as one which spends three or four times the length of time to cover the same distance. And so the picture is built up by the spot covering the screen in a series of faster and slower movements at the various points in order to convey the impression of a pattern corresponding with the televised picture.

The Velocity Modulation system has been developed until it has become perfectly practical, and it possesses advantages of its own. It has been suggested that it would be worth while to combine Velocity and Intensity Modulation. You will read more about this in later chapters in the book.

Interlaced Scanning. It has been found that flicker in television pictures can be reduced quite considerably by what is known as " Interlaced Scanning." This is the scanning of the picture in alternate lines. Imagine the picture to be divided up into definite strips—as indeed it is in the scanning process.

Instead of scanning each successive strip, however, the picture is first scanned at every other strip or line, as if every other hole in an ordinary scanning disc were stopped up. The picture is then scanned again, but this time along only those lines which were missed out in the first scanning. And the process is repeated continuously. If the lines were numbered, interlaced scanning would mean that first the odds and then the evens were scanned. At the receiving end the effect in the " looker " has twice the number of pictures per second, and although each picture has only half its lines these are merged into full detail by the persistence of vision quality of the eye.

Chapter 8

A SIMPLE TELEVISION RECEIVER

THE DISC-TYPE VIEWER—SUITABLE LAYOUTS—REFINEMENTS—THE FIRST PICTURE—FAULTS (NEGATIVE IMAGE, OUT OF PHASE, OUT OF FRAME)—MOTOR SPEED—UNSTEADY PICTURES—DISTORTION IN THE AMPLIFIER—CONTROL OF BRILLIANCE — WHITE-LIGHT LAMPS — IMPROVING THE PICTURE—PROJECTING THE PICTURE—FAULTS IN THE SCANNING DISC.

From the very earliest days of low definition television, the disc-type viewer has been, without a doubt, the most popular. Its chief merits are extreme simplicity and cheapness, while its only drawback, compared with other systems, is the fact that the image is somewhat restricted in size.

The reader, no doubt, understands the principle of the scanning disc by now, and it is proposed, in this chapter, to deal chiefly with the practical points arising from the construction of a complete viewer.

Let us examine, first, the requirements. The simplest form of viewer incorporates the following components: the disc itself; a motor to drive it at the requisite speed; a variable resistance for fine control of that speed; and a source of modulated light to place behind the disc.

Suitable Layouts. Fig. 40 shows a convenient layout of these parts. Indeed, this more or less settles itself, since the neon lamp (or whatever type is used) must be placed behind the disc at the right-hand extremity of a diameter. The control resistance has been divided into two; the greater part of it consists of the fixed tapped resistance R1, making it possible for R2 to be given a much lower value. This, of course, makes for easier control of speed.

The disc is shown mounted directly on the motor shaft. Some types of disc viewers employ an indirect drive, which does possess certain advantages, but does not. in any way, affect the basic principles.

The neon lamp is connected suitably to the output circuit of the television receiver, and varies with the modulation of the incoming signal. The whole business of the revolving disc is to divide the picture area 12½ times per second into 30 vertical strips, these being the figures employed for the low definition television service which is still, at the time of writing, being maintained on an experimental basis.

A GOOD LAYOUT

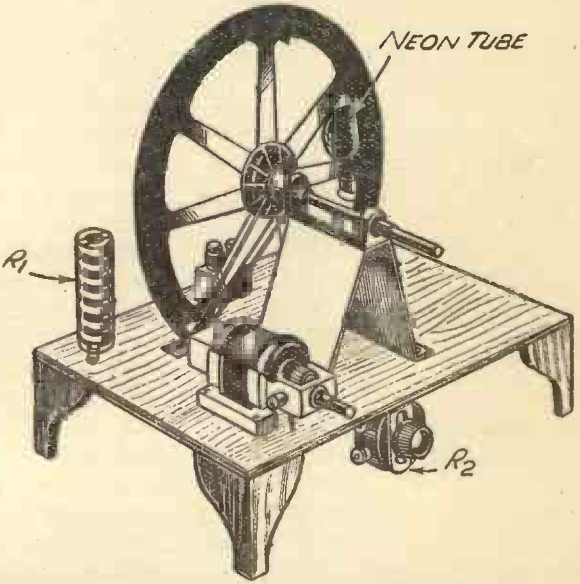


Fig. 40—A complete disc-viewer will generally be laid out on the lines suggested in this diagram. Note especially the position in which the neon tube must be placed

One can understand this operation better by means of a simple experiment than by reading many books on the subject. Illuminate the tube, and rotate the disc slowly in an anti-clockwise direction. A spot of light will be seen to move upwards, and at the precise moment at which it reaches the top edge of the picture aperture, the next spot, slightly to the left of the first, will appear at the bottom.

Switch on the motor, and watch the light-spot as the disc gains speed. It will turn into a vertical streak, which will be followed by other vertical streaks running parallel with the first. Thanks to persistence of vision, when the full speed is reached, the thirty streaks thus produced will give the effect of a rectangle of light.

If some form of modulation is now imposed upon the glowing neon lamp, various patterns will be observed by looking at it through the revolving disc; and if the modulation corresponds to a thirty-line television image, then a picture will be seen. Probably it will not, at the first attempt, be recognised as a picture, but that doesn't enter into the story at this stage!

Refinements. First, let us deal with the various refinements that may be introduced into the rather primitive viewer that has been described. The actual size of the image is determined by the spacing of the holes in the scanning disc. The distance, circumferentially, between any two adjacent holes may be regarded as the height, while the distance between the first and thirtieth holes, measured along the diameter of the disc, forms the width.

FOR EASIER VIEWING

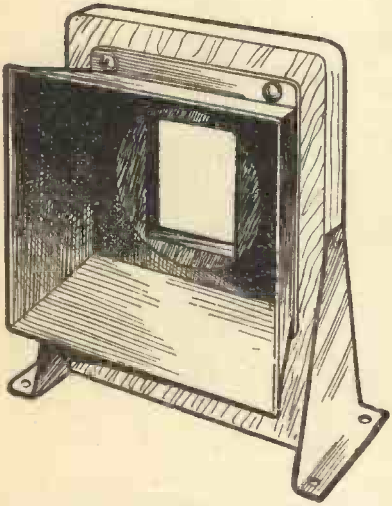


Fig. 41—A well-designed viewing tunnel incorporating a mask of correct size for the picture aperture

The average 16 in. disc gives, roughly, a breadth of $\frac{5}{8}$ in. and a height of $1\frac{1}{2}$ in. For the purpose of cutting off the unwanted "leakage" light from the tube, a mask of opaque material, with a hole of that size cut in it, may be placed immediately behind the disc. In front of it, to make viewing a more comfortable matter, we may introduce either a plain convex lens or some form of viewing tunnel. The latter will probably consist of one or two lenses mounted in a frame, with an opaque frame of suitable shape extending forwards (Fig. 41). Several types are marketed complete.

The whole viewer may conveniently be enclosed in a cabinet. If synchronising apparatus of the phonic-wheel type is also incorporated (and it is a very desirable refinement) it will be mounted on the same spindle as the disc itself. The controls on the front panel will then be the variable resistance for controlling motor speed, and the "framing" adjustment of the synchronising gear, which is some convenient means of moving the pole-pieces slightly with relation to the teeth of the rotating wheel.

The First Picture. We will now assume that the viewer itself is complete; that the neon lamp is suitably connected with the receiver; and that a transmission is just about to commence. Sound, of course, must be looked after by a separate receiver, but we will assume, for the time being, that the vision receiver is a good one, selective enough to receive our station clear of interference, and giving good reproduction both of bass and "top."

The first thing we shall see in our viewer will almost certainly be a meaningless collection of vertical streaks, with diagonal bars moving rapidly across the picture aperture. Our motor is not revolving at the right speed, and until it is, it is naturally impossible to obtain a steady picture. The disc must revolve at exactly 750 revolutions per minute, and we must carefully adjust the variable resistance until the movement of the picture slows down and eventually ceases.

Most scanning discs are provided with a stroboscopic device consisting of eight radial lines painted white. When viewed in the light of a neon tube or an ordinary bulb running from 50-cycle A.C., these lines will appear to be stationary when the correct speed is reached.

If the disc runs too fast, the pictures will move rapidly upwards; if too slowly, they will move downwards; and when we arrive at a point that is somewhere near the correct speed, we shall be able to spot each separate picture as it appears to pass upwards or downwards through the scanning aperture.

OUT OF PHASE

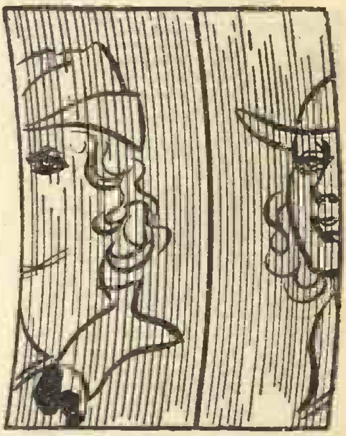


Fig. 42—The condition shown above results from the scanning being out of phase, although the motor is running at the correct speed

Faults. The odds are about thirty to one that the first intelligible picture we shall obtain will look like Fig. 42—due to a condition known as "out of phase." The very principle of disc scanning implies that our own disc shall be moving in perfect synchronism with the rotating disc (or mirror drum) at the transmitting end. In other words, as the B.B.C.'s light-spot starts at the right-hand bottom corner for its upward sweep, ours must likewise start at the same place.

In the case of Fig. 42, our light-spot is starting at the bottom of the picture, but not on the right scanning-line. Hence we have the picture in two sections, like a photograph that has been cut through vertically and been re-assembled the wrong way round.

Out of Phase. To merge the two halves into an intelligible whole, we must either increase or decrease the speed of the motor very slightly. This will cause the picture to "drift" upwards or downwards, and with each successive picture that passes the aperture, the dividing line will move by one scanning-line to the right or left until it eventually reaches its proper place at the extreme edge of the picture, which will then look like Fig. 43.

There is another point, however, which may be wrong still. We may obtain a "negative image." All the "blacks" are reproduced as "whites," and *vice versa*, exactly as in a photographic negative.

IN PHASE

Fig. 43—A slight alteration of motor speed will cause the picture in Fig. 42 to "drift" vertically until the division reaches one side of the picture, as above

Negative Image. This is easily corrected in most cases. If there is a transformer-couple stage in the receiver, it is only necessary to reverse the connections to one of the windings of the transformer—either primary or secondary.

If an output transformer is in use, the easiest thing to do is simply to reverse the connections to the secondary (output) winding. If no transformers are used at all, things are a little more difficult. The necessary phase change may be introduced into a resistance-coupled amplifier by adding (or subtracting) a stage of L.F., or by changing the method of detection.

For example, suppose we have a receiver with an H.F. stage, leaky-grid detector, and two R.C. stages. Should this give a negative image, we must either change the detector over to anode-bend, or add a third stage of resistance-coupled L.F. The use of a 1 : 1 output transformer, however, is strongly recommended, and a change-over switch may be provided for the secondary connections, so that a negative image can be instantaneously reversed (Fig. 44).

CORRECTION FOR NEGATIVES

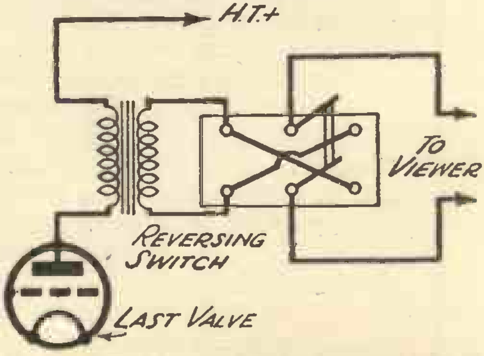


Fig. 44—An easy scheme for the correction of negative images by means of a double-pole, double-throw switch

MISS JOSEPHINE BAKER, THE FAMOUS AMERICAN COLOURED ACTRESS, DURING HER SUCCESSFUL B.B.C. TELEVISION BROADCAST. NOTE THE PHOTO-CELL UNIT ON THE LEFT AND THE MICROPHONE ON THE RIGHT

Plate 15

Plate 16

LAURIE DEVINE IN A STRIKING MAKE-UP DESIGNED FOR LOW DEFINITION TRANSMISSION

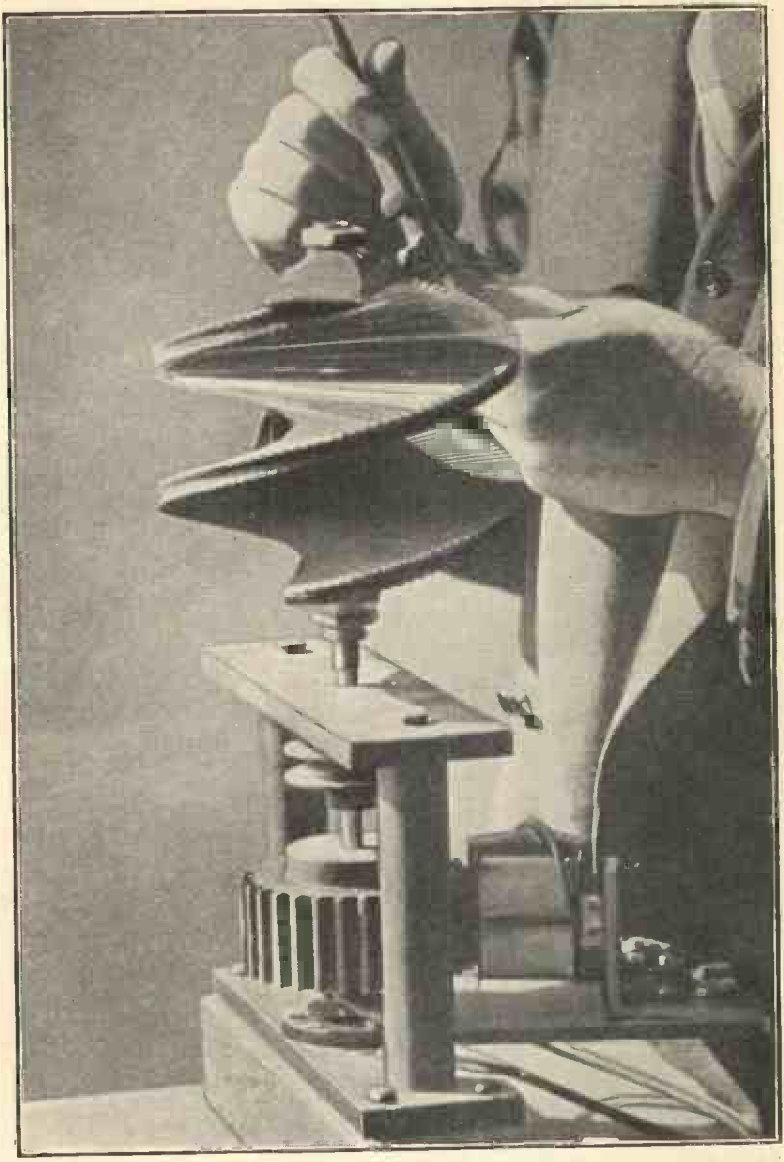
THE INVENTOR OF THE ICONOSCOPE

DR. VLADIMIR ZWORYKIN, INVENTOR OF THE ICONOSCOPE, WITH A NEW TYPE OF CATHODE-RAY TUBE FOR RECEPTION, WHICH HE HAS DEVISED

Plate 17

Plate 18

THE SOUND (LEFT) AND VISION CONTROL ENGINEERS AT WORK IN THE CONTROL ROOM OF THE B.B.C. TELEVISION STUDIO AT NO. 16. PORTLAND PLACE, LONDON.



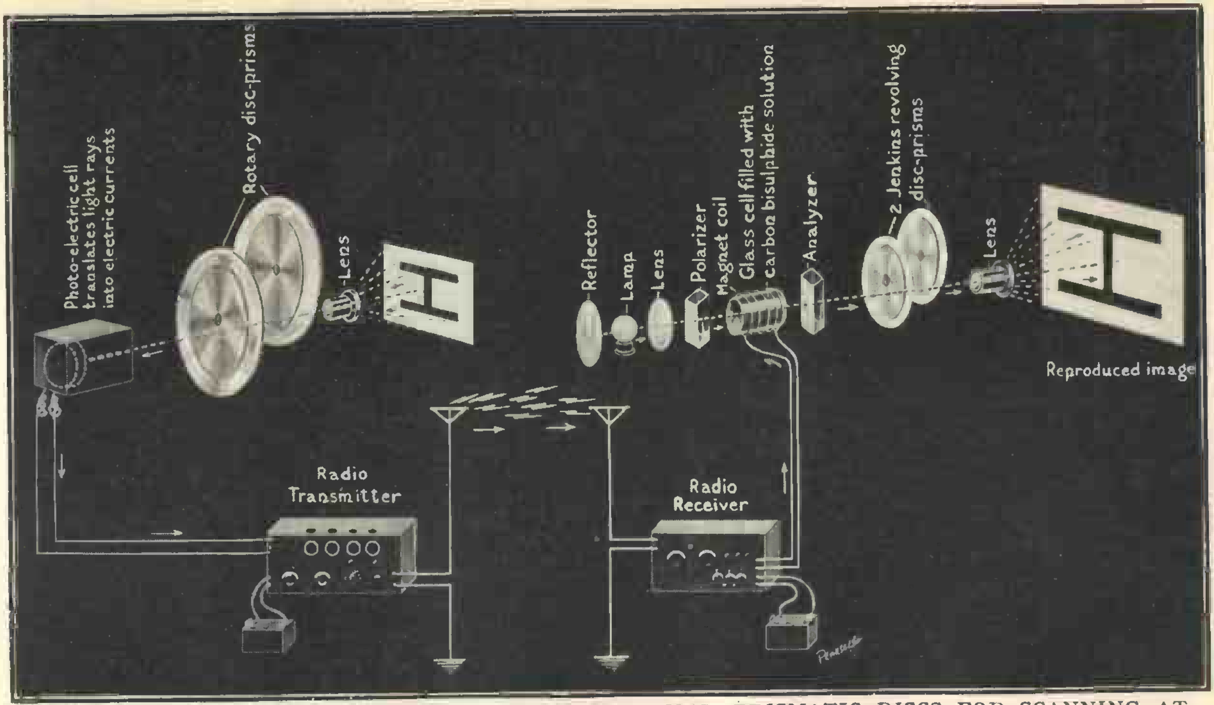
A MIRROR-SCREW MECHANICAL VIEWER FOR HIGH-DEFINITION RECEPTION MADE BY A GERMAN FIRM

Plate 19

THE CONTROL PANEL OF THE TELEVISION EQUIPMENT AT BERLIN. TRANSMISSION IS ON ULTRA-SHORT WAVES FROM THE WITZLEBEN STATION

AN INDICATION OF THE INTENSELY BRIGHT FLOOD-LIGHTING NECESSARY IN THE EARLIER DAYS OF TELEVISION IS PROVIDED BY THIS PHOTO OF BAIRD HIMSELF BEING TELEVISED BY ONE OF HIS FIRST TRANSMITTERS

Plate 21



THE JENKINS TELEVISION SYSTEM, WHICH EMPLOYED PRISMATIC DISCS FOR SCANNING AT BOTH TRANSMITTING AND RECEIVING ENDS. LIGHT CONTROL AT THE RECEIVER WAS BY MEANS OF A KERR CELL ARRANGEMENT

Out of Frame. The next condition that can arise is "out of frame" adjustment, although this is only possible when synchronising gear is in use. The effect is shown in Fig. 45—a picture divided horizontally into two, in a manner reminiscent of the very early days of the "movies"! This simply means that the pole pieces of the phonic-wheel synchroniser are "pulling" the teeth of the rotating wheel at the wrong place. A small movement of the pole-pieces (always provided for in kits and complete assemblies) will "pull" the black synchronising bar downwards or upwards until the picture fits properly into the frame.

SYNCHRONISER FAULT

Fig. 45—A movement of the pole pieces of the synchroniser suffices to cure the fault shown above, which only occurs when synchronising gear is used

Another fault that may easily be present, although it is not really a radio matter at all, is the presence of "streaks" or "flashes" superimposed upon the picture. These may be caused by external noises or atmospherics, but quite probably they will be due to sparking at the commutator of the motor driving the disc. This must be "silenced" by the use of two 1 mfd. condensers connected across the brushes, with the centre point earthed (Fig. 46).

STOPPING SPARKING

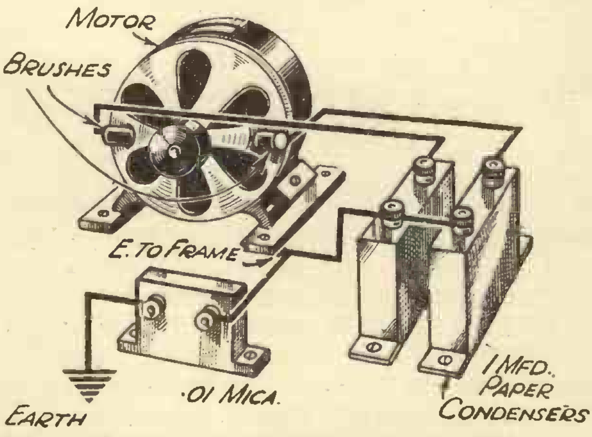


Fig. 46—"Streaks" across the picture are often due to motor sparking, which is easily cured by the provision of two condensers across the brushes

By the time all these points have been rectified, the only troubles that can occur will be unsteadiness and distortion. The former is purely a mechanical trouble, the latter purely radio. Drifting pictures, obviously, can only be caused by variations of motor speed. These may be due to a fluctuating mains voltage, a bad motor, a dirty commutator, or brushes that need renewing.

Unsteady Pictures. Synchronising gear, however, should hold the picture steady against all small variations, if the motor speed is very carefully adjusted. One needs to develop a very delicate touch on the motor control rheostat, and to avoid sudden or violent movements. The knack of controlling speed within the fine limits necessary is only acquired by practice.

AN ESSENTIAL CONTROL

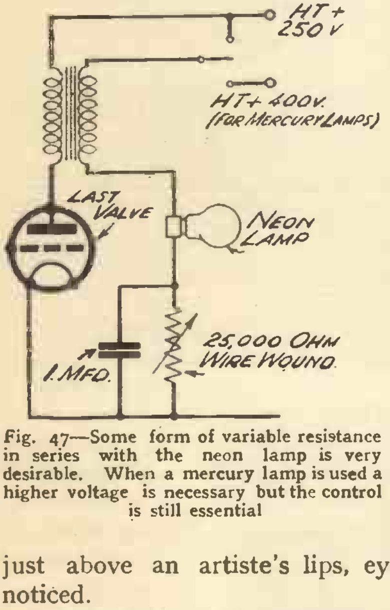


Fig. 47—Some form of variable resistance in series with the neon lamp is very desirable. When a mercury lamp is used a higher voltage is necessary but the control is still essential

Distortion of the picture may take several different forms. A marked lack of bass-response in the amplifier will result in a picture that is lacking in detail, and one that may have white " shadows " above all the dark parts. If an artiste with dark hair appears to have a vague kind of white hat perched on the top of his head, and reaching to the top edge of the picture, loss of bass may be assumed to be the trouble.

Distortion. On the other hand, an excess of " top " will result in an accentuation of all contrasts, together with heavy dark lines above any horizontal lines in the subject being televised. A kind of black border just above an artiste's lips, eyebrows, shoulders, etc., will be noticed.

Overloading of the amplifier, or over-modulation of the neon tube, will produce similar effects with much greater severity. All contrasts will be very greatly exaggerated.

Control of Brilliance. At this point, it is as well to mention that a control of brilliance should be available. When a neon tube is used, we should be able to control the steady voltage applied to it, so that it can be set at the value which best suits the strength of the incoming picture signals. Fig. 47 shows a suggested output circuit, using a 1 : 1 transformer and a variable resistance to control the brilliance of the picture.

White-light Lamps. It is not essential to use a neon tube. Several types of lamps giving a whiter and more intense light have been developed, among them being the White-Line Lamp (intended originally for mirror-screw work) and the T.I. Lamp, for projecting pictures through a disc on to a screen.

These types can also be used for direct viewing, but they all need a rather greater striking voltage than the neon tube. The alternative supply (400 volts) shown in Fig. 47 is intended for use with these lamps, and is unnecessary if a neon tube is used, the receiver H.T. being sufficient for that type of tube.

The other lamps have, as a rule, a much smaller area than that of the glowing plate of the neon tube, and accordingly cannot be viewed directly without the addition of a lens and a ground-glass screen, placed behind the disc, as in Fig. 48. The addition of a small concave mirror behind the lamp will improve matters still further.

FOR BRIGHTER PICTURES

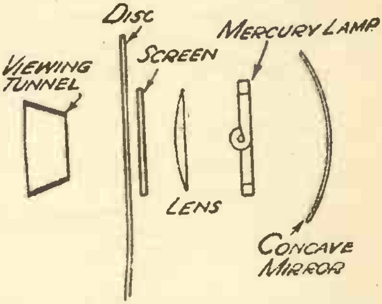


Fig. 48—The use of a mercury lamp with a mirror, lens, and ground glass screen will give pictures that are much less tiring to the eye than those obtained with a neon tube

Improving the Picture. Really brilliant pictures can be obtained by the use of these lamps, and may be viewed in daylight or with the room lighting switched on.

Since a higher voltage is applied to them, it follows that a stronger picture signal will also be required to obtain really full modulation. The average two- or three-stage amplifier, with a large power-valve for the output, will usually give all the necessary variation of voltage. It simply means that the full output of the receiver can be used, whereas it will generally have to be reduced considerably when a neon tube is in use.

Incidentally, it is as well to mention that the White-Line and T.I. lamps operate at quite a high temperature, and that ventilation should be arranged for them. Working in the open, they will be quite safe, but if they are boxed in it is essential that an opening should be left above them or things may become unpleasantly warm.

Projecting the Picture. An interesting development of direct viewing through a disc is the " projection " method of receiving pictures. A lamp like the " T.I." giving a small point of intensely brilliant light makes it a fairly easy matter. Fig. 49 shows one of the systems commonly employed.

Behind the lamp is placed a concave mirror (A), and between the lamp and the disc is an ordinary plano-convex lens (B). The joint effect of these is to provide a brilliant circle of light of sufficient size to cover the scanning aperture.

PROJECTING IMAGES

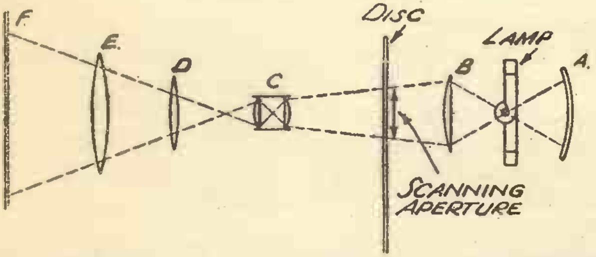


Fig. 49—Quite large images may be projected on to a screen by using the combination of lenses shown above. The whole assembly is usually placed in a cabinet to avoid loss of light

In front of the disc is a small projector-combination (C), and finally a pair of large lenses (D and E), giving a large image on the ground-glass screen (F).

With certain combinations of lenses the image may be inverted, but this involves no trouble, since we simply use the " wrong side " of the scanning disc, and project an inverted image so that it resumes its normal position when viewed on the screen.

The whole assembly of lenses, together with a " viewing-cabinet," is sold in kit form, and is claimed to give results that do not fall far short of those obtained with a mirror-drum projector.

Faults in the Scanning Disc. Before closing this chapter it would be as well to remark upon a few faults that can arise from the scanning disc itself. These have purposely been omitted, as being purely mechanical, but the television enthusiast must know what to look for, in case the disc he uses happens to be a poor specimen.

The holes cut in the modern disc are square, and are set at angles of 12 degrees to each other round the circumference of the disc. Each hole is off-set from its neighbours by an amount equal to its diameter.

An incorrectly-punched hole therefore has two opportunities of going wrong. It may be displaced from its correct position either angularly or laterally.

Lateral displacement is the more obvious to the eye, since it results in light or dark vertical streaks in the picture, according to whether the adjacent holes suffer from overlap or " underlap."

Angular displacement will result in one or more of the scanning-lines being out of place in a vertical direction. If the black synchronising bar at the top or bottom of the picture appears to have a very jagged edge, then a certain amount of angular error is present.

The modern scanning disc, however, is an extremely accurately made piece of work, and these faults are not often encountered.

High definition television is being covered in other chapters, but it seems appropriate to mention here that discs for 180 and 240 lines have already been developed, and that an understanding of the projection method outlined above will be extremely useful to the reader.

Direct viewing will be out of the question, owing to the minute size of the picture, but projected pictures through a disc promise to be within the sphere of practical politics.

L.H.T.

Chapter 9

SYNCHRONISING A MECHANICAL VIEWER

GENERAL REQUIREMENTS—THE BAIRD TOOTHED WHEEL—SUITABLE CIRCUITS—USE OF 50-CYCLE MAINS—EMPLOYING SYNCHRONOUS MOTORS—HOW SYNCHRONOUS MOTORS WORK—EARLY SYNCHRONISING SCHEMES—CONTROLLING LOCAL GENERATORS — A THYRATRON SCHEME — INTERESTING METHODS—MODULATION EFFECTS—HOW MECHANICAL SYSTEMS SCORE.

In dealing with methods of synchronising a mechanical television viewer, we need be very little concerned with the method by which the synchronising pulses are obtained at the transmitter. With practically all modern systems these pulses are superimposed on the actual picture modulations.

The pulses may never be greater than the maximum picture modulation or, on the other hand, they may rise considerably above it. Also it is possible they may be transmitted separately on a separate channel. This was the case with most of the earlier systems of synchronising.

The word synchronising as applied to television covers two factors. Synchronism indicates that not only is the spot of light at the receiver always simultaneously on exactly the same point of the picture as the spot of light at the transmitter, but the scanning apparatus at the receiver is also moving at the identical speed of that at the transmitter.

However, so long as we have isochronism, namely, running at the same speed, it is a simple matter with nearly all mechanical systems to adjust for synchronism. This, as explained in the preceding chapter, is normally obtained by temporarily varying the speed of the motor, or altering the framing by, for instance, moving the relative position of the synchronising gear.

As a general rule it may be taken that all of the schemes discussed in this chapter may be applied to any viewer which has a rotating device of some sort or the other for scanning purposes. The real object of our synchronising is to see that the revolving device at the receiver runs at exactly the same speed as that at the transmitter, and varies its speed exactly in accordance as well.

Small variations are bound to take place, and their importance is immediately obvious when it is stated that for satisfactory television work it is necessary to have an accuracy somewhere in the region of one part in seven million.

The Baird Toothed Wheel. First of all we will describe the toothed-wheel type of synchroniser that is used with the disc type of viewer described in the previous chapter. We shall deal with it as applied to 30-line working, but it must be appreciated that it could equally well be used with higher-definition working.

It is an important principle, and a good understanding of it helps the grasping of mechanical synchronising in general.

FOR SYNCHRONISING MECHANICAL VIEWERS

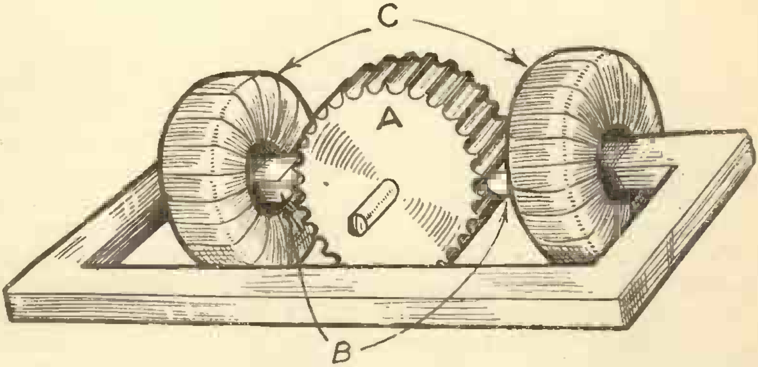


Fig. 50—The synchronising current pulses are fed through the coils C and magnetise the poles B, and keep the toothed iron-wheel A rotating at the correct speed

Since there are 12½ pictures per second, each with 30 lines, the frequency of the synchronising pulses will be 375 per second. There will be a strong pulse of current available this number of times per second. How are we to make them hold the speed of the scanning disc constant ?

It is achieved by means of the apparatus illustrated in Fig. 50. The wheel A is made up of iron laminations and is attached to the spindle of the disc. Not, it should be noted, the motor spindle, unless the disc is directly driven.

On exactly opposite sides of this wheel are two pole pieces of soft iron, B. These are yoked together and each carries a winding of insulated wire, C.

Through these coils, which are joined together, are passed the synchronising pulses. The pole pieces thus become magnetic for a fractional period 375 times a second.

The wheel A has 30 teeth on it. Therefore, supposing the disc to be running exactly at the right speed, one of these 30 teeth will be exactly opposite each pole piece B, 375 times a second.

Now look at Fig. 51. This is a close-up of one pole B and two teeth. The distance between the teeth, incidentally, is greater than the width of each tooth, and the gap between the teeth and the pole pieces should be as small as mechanical considerations will permit.

HOW IT WORKS

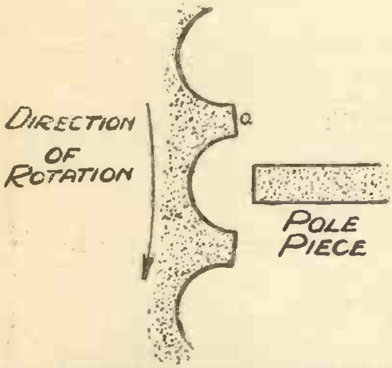


Fig. 51—This diagram helps to explain how the pulsating currents in the coils of the Fig. 50 device control the speed of the toothed wheel

When the speed is just right, the magnetic pull from the pole pieces on the teeth will have no effect on the disc speed. But suppose the disc is running slightly slow, and the teeth are in the position indicated in Fig. 51 when the synchronising pulse magnetises the pole piece. The effect will be for tooth "a" to be attracted to the pole piece, and over a number of teeth this produces a quickening up of the disc speed until it is exactly right.

Similarly, if the disc is running too fast, the pole piece will tend to hold back the teeth as they try to pass away from it. The result will be a slowing down of the disc until the right speed is attained. Naturally, every attempt should be made to get the disc running as near the correct speed, or just a fraction faster, as is possible. Otherwise the synchronising device will have too much work to do and will never succeed in speeding up or slowing down the disc sufficiently.

Suitable Circuits. The simplest connections for the synchronising device are shown in Fig. 52. It will be seen

THE SIMPLEST SCHEME

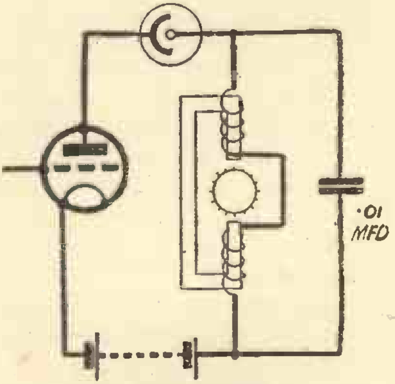


Fig. 52—The simplest circuit for applying a toothed-wheel synchroniser to a mechanical viewer which employs a neon tube light source

that it is directly in series with the neon tube being supplied by the same output valve. It is worth mentioning here that the two coils on the synchroniser must be joined together a certain way.

When working properly, one pole is north and the other south, magnetically. If the coils are joined together wrongly, their magnetising effects will oppose one another, and there will be little, if any, attraction at the poles. The best way to test for correct connection in practice is to try both ways, and note which provides the strongest magnetic effect.

With reference to Fig. 52 it should be noted that the synchronising windings are by-passed by a fixed condenser of .01 mfd. This is to prevent the inductance of the coils affecting the modulation through the tube. It also keeps most of the modulation frequencies out of the synchroniser coils, although this is of little importance. Only certain modulation variations are likely to affect the synchronising, and this point is dealt with later in this chapter.

DIVIDED OUTPUT

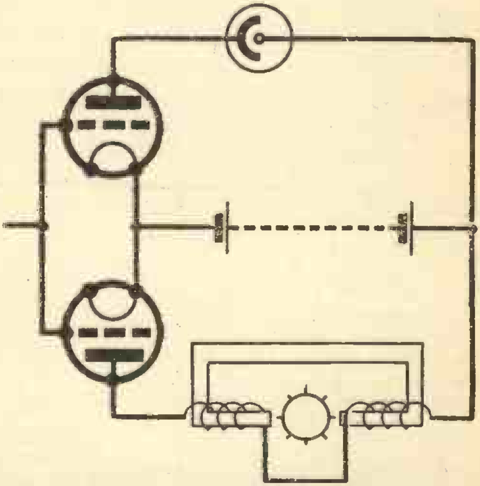


Fig. 53—In this circuit a separate valve is used to feed the synchroniser. Note that the by-pass condenser of Fig. 52 is not necessary in this case

A preferable scheme of connections is to separate the outputs of picture modulations and synchronising impulses as in Fig. 53. In this circuit it is permissible to obtain stronger synchronising pulses by using a steeper slope valve with a smaller grid-swing for the " lower " valve as it has only to handle a frequency of 375, and also there is little harm in its being overloaded somewhat.

When the output is split this way, it is possible to add extra amplification to the synchronising pulses. This is really desirable for very steady pictures without swing.

About 2 to 4 watts output is the figure to aim at for good synchronising, and a special transformer that peaks sharply at 375 cycles per second is a great help. It would be connected up as in Fig. 54.

Use of 50-Cycle Mains. Since 50-cycle mains are more or less standardised in this country, a certain amount of experiment has been carried out in their use as an aid to synchronising. And for this purpose an 8-toothed wheel, working with magnetised pole pieces in the same way as the 30-toothed wheel, has been developed.

First of all let us consider why 8 teeth are used. The toothed wheel is arranged on the disc spindle in this case as before, and therefore revolves at 12½ times per second.

It will thus be seen that a tooth passes each pole piece 100 times per second. This is obtained, of course, by multiplying 8 by 12½. Consequently, all we need to hold the speed constant at 375 revolutions per second is to magnetise strongly the pole pieces 100 times per second also.

OBTAINING STRONG SYNCHRONISATION

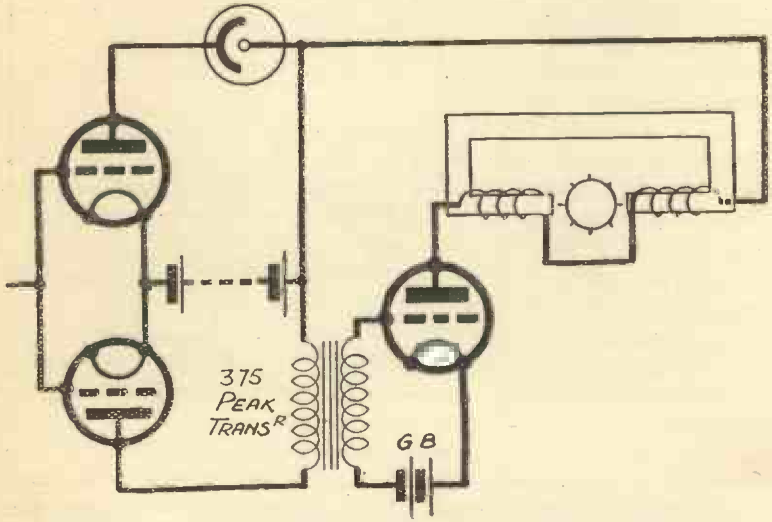


Fig. 54—Steadier pictures can often be obtained by employing an amplifying stage in the synchroniser circuit. A coupling transformer tuned to the synchronising frequency assists in obtaining a high step-up for the amplifying stage

This is what our 50-cycle current from the mains, passing through the magnet windings, achieves. It must be remembered that a cycle of current consists of a rise from zero to a maximum, followed by a fall to zero again, and then another rise to maximum in the opposite direction, followed again by a fall to zero. Thus our 50-cycle mains give us 100 pulls per second, since it is immaterial, from a magnetic point of view, in which way the current is flowing.

The great advantage of the 8-toothed wheel is that it can be supplied with as powerful a current as we desire, because the source of its power is the mains supply. But it does not enable us to dispense with the normal synchroniser entirely, as we shall see in the next paragraphs.

Employing Synchronous Motors. A synchronous motor is one which is designed to run at a predetermined fixed speed. It is also designed to work on one particular frequency of alternating current, and on such a current will revolve only at the predetermined speed. Of course, if a current of a different frequency were applied to it, it would still work, but at an unwanted speed, and only at that unwanted speed.

Synchronous motors are quite common on A.C. radiograms. They are designed to revolve at 78 revolutions per minute, the correct speed for record reproduction, and are usually for use on 50-cycle mains.

On first consideration it would appear that such motors are ideal for television work since 50-cycle mains are so common, and that with them no synchronising signals need be transmitted. But there is a " snag." And it applies also to the 8-toothed synchronising wheel we have just described.

It will be remembered that at the beginning of this chapter we mentioned that the receiving scanner must be able to vary exactly in accordance with the slight variations that are bound to take place at the transmitting end. Even with transmitter and receiver both working on 50-cycle time-controlled mains the variations between them would be too great for satisfactory television working.

The variations over several months would be so small as to be immaterial, as witness the great accuracy of electrical time clocks. It is the momentary variations that we are up against. And even with transmitter and receiver working on the same mains supply, it has been proved in America, where much work has been done on these lines, that unavoidable variations between transmitter and receiver can take place.

At the same time the use of synchronous motors enables the speed to be kept so nearly right that they are a great aid to synchronising, and for this reason are almost bound to be found on mechanical systems of the future.

How Synchronous Motors Work. In view of their great value to television work, we will go into the question of how synchronous motors work. Their principle is quite simple.

Actually their basic idea is almost the same as that of the toothed-wheel synchroniser. The main difference being that they provide the power as well as control the speed of revolution. If you increased the power of the synchronising pulses supplied to a toothed-wheel device sufficiently, they would actually keep the disc revolving once it had been started. And that gives us the simplest of synchronous motors, commonly known as a phonic wheel.

AN IMPORTANT PRINCIPLE

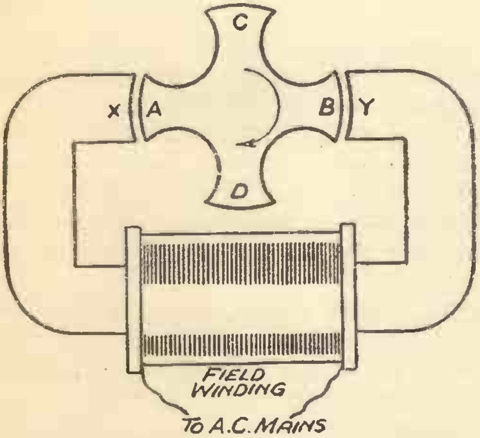


Fig. 55—This is the simplest form of a synchronous motor, a device which works on A.C. and will only revolve at one predetermined speed

Fig. 55 shows the practical arrangement of a simple synchronous motor. It has a four-pole armature and is not self-starting. The A.C. current passing through the field winding magnetises the poles X and Y. These attract the armature poles A and B, and there things rest unless the motor is started in the direction of the arrow by giving the armature a spin.

The sequence of events when the armature is under way is illustrated by Fig. 56. When the current is at a maximum the armature poles are opposite the field poles. But the momentum from the starting swing carries

WHY THE SPEED OF REVOLUTION IS FIXED

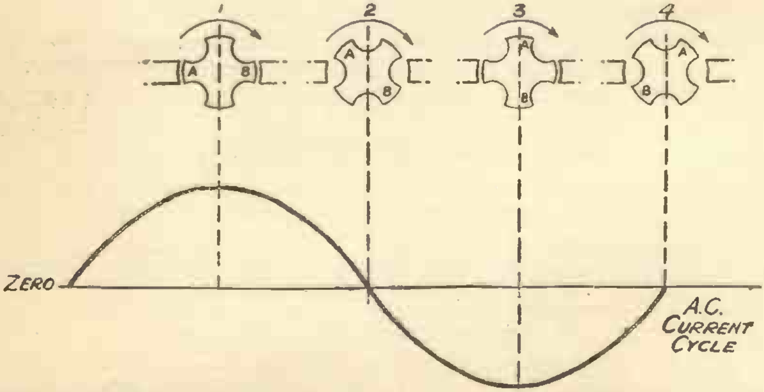


Fig. 56—Explaining what takes place in the motor of Fig. 55 during the period of one complete cycle of A.C. Note that the rotor revolves exactly half a turn

them past as the current decreases, until the second position is attained when the current is zero.

When the current increases the field poles attract the next two armature poles which are moving towards them, reaching the third position at maximum current in the opposite direction. At zero current at the end of the cycle the poles are as at four, ready for the next cycle.

This motor would do 25 revolutions per second on 50-cycle mains. By arranging the number of poles on the armature to a suitable number in relation to the frequency of the mains, any number of revolutions per minute can be obtained.

A PRACTICAL ARRANGEMENT

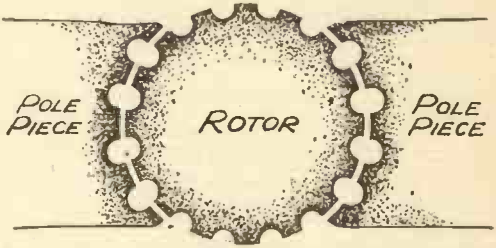


Fig. 57—In practice the field poles of a synchronous motor usually cover several of the poles on the armature or rotor, as illustrated by this diagram

Sometimes the poles are arranged as in Fig. 57, and it is possible to make the motor self-starting by special arrangements.

EXPLAINING THE TUNING-FORK SYNCHRONISER

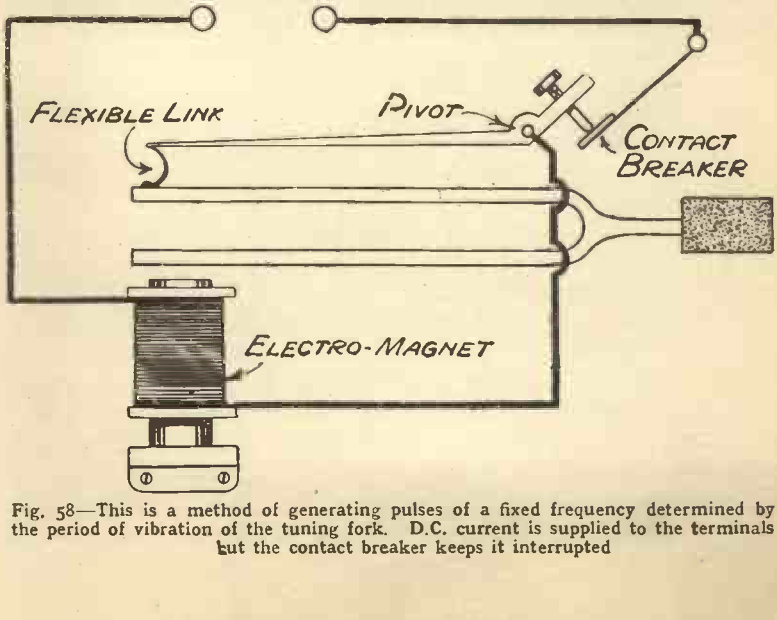


Fig. 58—This is a method of generating pulses of a fixed frequency determined by the period of vibration of the tuning fork. D.C. current is supplied to the terminals but the contact breaker keeps it interrupted

On elaborate synchronous motors the field winding may be run on D.C., the A.C. being fed to windings on the armature. But the principle remains the same.

Early Synchronising Schemes. In original experiments in television, synchronising was given little attention, motors being either directly connected, or a separate channel being used to transmit a motor-control pulse. But as the possibilities of television service advanced, the undesirability of a separate channel focused attention on synchronising systems.

Dr. Karolus used an electrically driven tuning fork to provide current for a synchronous motor at the transmitter, and a similar tuning fork at the receiver. But the system, apart from being very expensive, did not prove sufficiently accurate.

The principle of the electrically driven tuning fork, however, is interesting, and is illustrated by Fig. 58. When the magnet attracts the fork the circuit is broken and the fork returns to its original position, turning on the current again. The fork is thus kept vibrating at its natural frequency.

Another system which proved more effective was to govern a synchronous motor by means of a local crystal-controlled valve oscillator.

But on the whole little success has been achieved without a transmitted synchronising signal.

Controlling Local Generators. When a separate channel was employed for the synchronising signal, either of the two systems just mentioned were perfectly satisfactory, a constant frequency being transmitted and used to control the local generators. The usual method of control was to drive a separate small synchronous motor by means of the received constant frequencies.

But the need of a separate channel was a big drawback, and led to the development of the superimposed synchronising signal. This, of course, could be employed in a similar way to control the locally generated currents.

But, as already explained, we now have standardised mains to drive synchronous motors, and these require but slight correction to ensure absolute synchronism.

A Thyratron Scheme. While dealing with locally produced constant frequencies, controlled by synchronising pulses, there is a similar scheme that has been used with ordinary disc viewers that is worthy of note. A tip has been taken from the time-base circuits of the cathode-ray experimenters, which are fully dealt with in later chapters.

The scheme is best followed from the circuit of Fig. 59. A Thyratron or other gas-discharge tube is connected so that it discharges a condenser at 375 times a second, or rather, just under this figure.

The synchronising pulses are then fed to the grid, and these keep the circuit working at the right speed. The synchronising pulses in this case do electrically exactly what they do mechanically in the case of the toothed wheel.

If the tube is late flashing over, they oppose the bias voltage and cause the tube to discharge the condenser earlier, thus speeding up working.

Interesting Methods. Mihaly suggested a method of super-imposing the synchronising signal on the vision channel before the present black bar idea was introduced, which consisted of short-circuiting the photo-electric cell six times per revolution of the scanning disc. This was achieved by means of a commutator attached to the disc shaft.

A MODERN METHOD

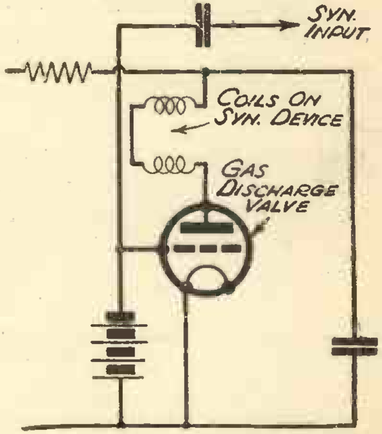


Fig. 59—Locally produced synchronising currents, controlled by the synchronising signal, may be produced by the aid of a gas-discharge tube connected up in the above manner

The arrangement at the receiver was to be on the lines suggested in Fig. 60. The pulses are amplified up until they are sufficiently strong to control a six-point phonic wheel.

AN EARLY IDEA

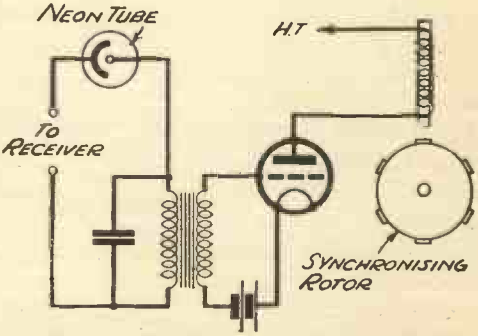


Fig. 60—This simple six-poled synchroniser may be considered as the forerunner of the modern toothed wheel

Fig. 61 shows the Baird method used before the introduction of the toothed wheel. The commutator is on the disc shaft, and so long as it is revolving at the right speed, the two brushes are always on the same segment during one complete picture line.

If the speed varies, the brushes get on to different segments, the relay ceases to be shorted, and current passes through it, the resistance in the field winding is shorted and the heavier field current causes the motor to slow. At the change over from one line to another, when the brushes are bound to be on different segments, there is no current flowing in the output circuit due to the presence of the black band. Thus the speed is not upset during normal changes from one segment to another. With this scheme the motor is run slightly faster than the desired speed.

FOR LOCAL CONTROL

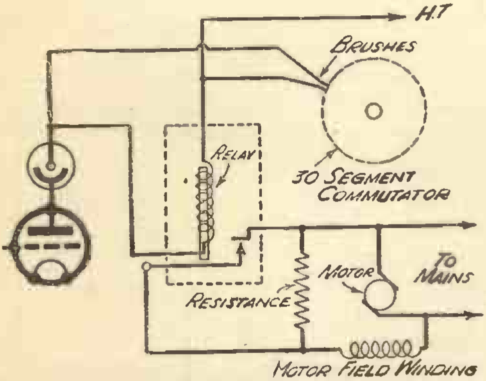


Fig. 61—No synchronising pulses had to be transmitted with this early arrangement for keeping the speed of the receiver motor approximately correct

Modulation Effects. With simple synchronising systems in which the synchronising signals are equal only to maximum picture modulation, there is always a danger that a black part of the picture near the top may run into the black band and be "mistaken" by the synchroniser for the synchronising signal.

The use of a local gas-discharge tube as already described, or a peak-tuned transformer, tend to avoid this possibility. But television workers have devised ways of overcoming it.

FILTERING THE PULSES

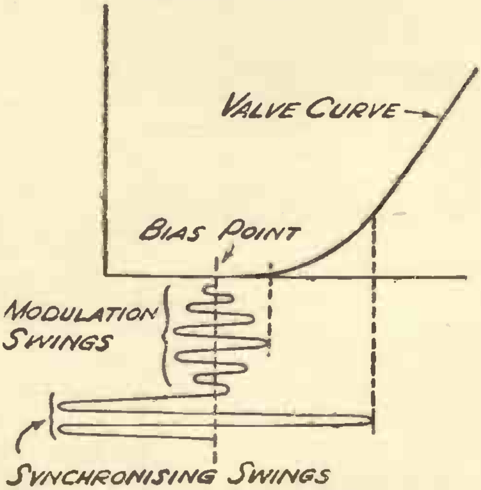


Fig. 62—To prevent picture pulses acting as synchronising currents, demodulation of the synchronising currents may be attained by using an over-biased valve. The above diagram shows how the modulation grid-swings occur "off" the valve's characteristic curve

One is to have the synchronising signal much stronger than maximum modulation for the picture, and to cut out all the picture modulation by means of a valve so biased that it takes no account of the picture modulations. This is illustrated by Fig. 62.

Another scheme used by the Marconi Co. was to arrange the synchronising impulses in the opposite direction to the picture modulations, and to deal with them by means of a separate group of valves at the receiver.

Yet another scheme is to arrange the synchronising signal circuits to have a fairly long time constant, so that they take little account of the quick variations of the picture modulation.

How Mechanical Systems Score. In practically all mechanical systems the question of synchronising is considerably easier than it is in the case of cathode-ray working. The reason for this is quite simple.

In a cathode-ray system, there are two synchronising frequencies that must be applied to the tube and kept dead constant the whole time. If either of them goes out it will upset things, and because one is maintained right, it does not mean that the other must necessarily be right also.

In most mechanical systems the positioning of the lines is a fixed factor in relation to the disc, mirror drum, or other device that produces the number of pictures per second. So long as this device rotates at the right speed the number and positions of the lines is also bound to be correct. Centring the picture, or avoiding it being split, is all that then has to be considered.

The general principles that have been used up to the present time, and which have been described in this chapter, will without doubt apply to the new mechanical systems that may be developed in the future for high-definition working. And as already indicated, synchronous motors, simply controlled by the synchronising pulses, are likely to be the system adopted in the future.

A. S. C.

Chapter 10

MIRROR DRUM AND OTHER MECHANICAL SYSTEMS

GENERAL REMARKS—THE MIRROR DRUM ITSELF—METHODS OF USING—STEADY LIGHT SOURCES—HOW THE KERR CELL WORKS—KERR CELLS FOR HIGH-DEFINITION WORK—MIRROR DRUM VIEWERS—OTHER DISC SYSTEMS—LENS DISC AND JENKINS DISCS—THE MIRROR SCREW—SCOPHONY—MIRROR DRUM VARIATIONS—VIBRATING MIRRORS.

In Chapter 8 the simplest form of mechanical television viewer was described. It employed a disc with a spiral of tiny holes punched in it. This disc, known as a Nipkow disc, was invented about 40 years or so ago, and has a number of disadvantages.

In view of these disadvantages, chief amongst which is the difficulty of getting sufficient light through the small holes to permit good projection of the picture, many other forms of mechanical scanning have been invented and developed. Perhaps the most popular and successful of these is the mirror drum.

Mirror drums of varying forms are employed in many different television systems to-day, so that the best way to approach the subject is to describe first of all the mirror drum unit itself, and then to deal with the way it is put into use in practice.

THE MIRROR DRUM

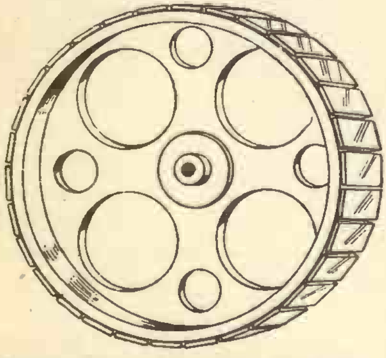


Fig. 63—The essentials of the mirror drum. Each mirror is tilted slightly in relation to the adjacent ones

For purposes of description we will consider a mirror drum for 30-line work. This will enable helpful comparisons to be made with the 30-line disc viewer to which we have just referred. At the same time it must be emphasised that the mirror drum is applicable to high-definition work, the only limit to the number of lines with which it can be used being entirely mechanical considerations.

The Mirror Drum Itself. Fig. 63 shows the simplest form of a mirror drum. It consists simply of a narrow drum, around the circumference of which are arranged 30 small rectangular mirrors. Across their smaller dimensions these mirrors are all at right-angles to the radii joining their middle points to the centre of the drum.

MOVING THE LINE

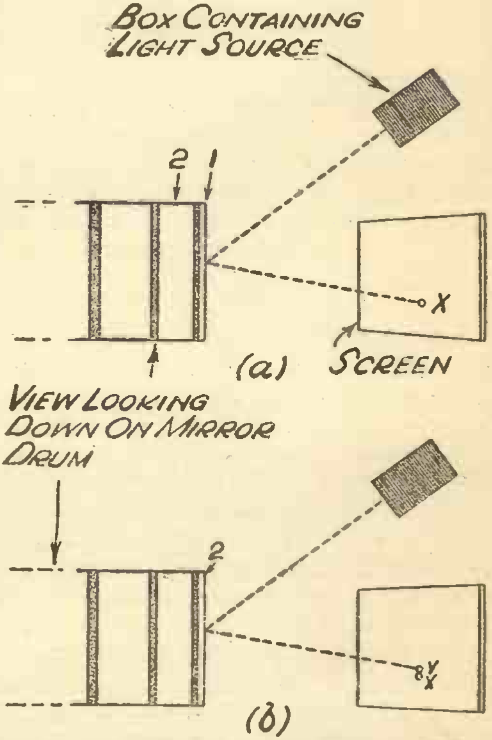


Fig. 64—This diagram shows how the angle of each mirror is just sufficiently different from the next one, to cause the spot of light to move across the screen the width of one line of the picture

Along their larger dimension they are all at slightly different angles. Each mirror has charge of one line of the picture, and the way in which the mirror drum achieves scanning as it revolves is as follows.

First of all consider mirror 1 in Fig. 64(a). With the drum stationary, the spot of light is reflected by the mirror on to the screen at the point X. In Fig. 64(b) the light is shining on mirror 2, which is at a slightly different angle from mirror 1. The result is that the spot of light now appears on the screen just to the side of the spot X, namely at Y.

Similarly, each mirror being at a slightly different angle, they will reflect the spot of light to different points from left to right across the screen. Each successive mirror will move the light slightly farther across the screen.

Now for Fig. 65. Here we are dealing with the mirror 1 the whole time, but looking at the drum from the side instead of from above. As the drum is revolved in the direction of the arrow, the angle at which the light beam strikes the mirror will vary; consequently the angle of reflection will vary and the spot will trace a line up the screen from bottom to top.

THE PATH OF THE SPOT

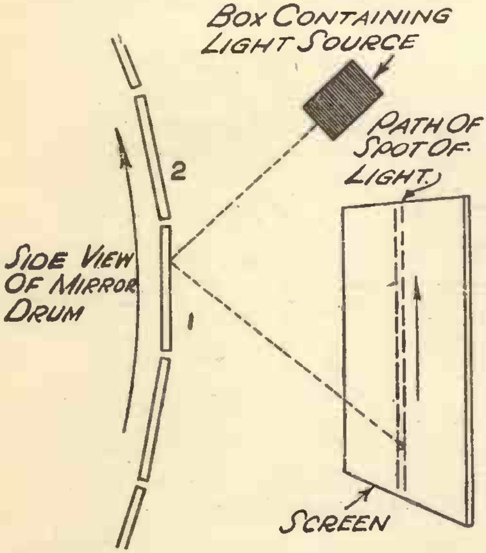


Fig. 65—As the drum revolves each mirror in turn causes the spot of light to traverse the screen from the top to the bottom

But as the drum revolves, mirror 2 and all the other mirrors will trace similar lines up the screen, and each line will be slightly to one side of the preceding line.

Thus when the drum has revolved once, thirty lines will have moved up the screen and we shall have scanned the whole picture area. The number of times per second the picture area is scanned depends simply on the number of revolutions made by the drum.

Methods of Using. The mirror drum is used in conjunction with a modulated light source just as in the case of the disc. The picture, however, is viewed on a screen. This may be arranged as in Fig. 66(a) where light is reflected from an opaque screen as in cinematograph pictures, or it may be viewed on a translucent screen such as a piece of ground glass, as in Fig. 66(b) (The lens systems have been omitted for simplicity.)

The second is the usual method adopted because it requires less light, and considerable output from the receiver is needed to modulate a powerful source of illumination.

The source of light can take the form of a crater-type neon tube in which the luminosity is concentrated at one point, or it may be a mercury-vapour or helium-vapour tube. The latter are much more common because the neon tube hardly provides sufficient illumination for practical purposes.

Mercury filled tubes give a greenish-blue light and helium a blue light. A tube which has proved very successful is the " TI " lamp. This employs a mixture of the two gases.

Steady Light Sources. Since we want a powerful light for our mirror drum, methods of varying the intensity of a local source of light have been much sought after. An ordinary electric light bulb whose brilliance varies with the voltage applied to the filament is unsatisfactory because of its lag in responding to voltage variations.

A source which will respond to voltage variations without any appreciable lag at all is necessary. Recently a special form of modulated arc has been developed, but this has the drawback for ordinary purposes of requiring a tremendous power input to control it.

TWO METHODS OF VIEWING

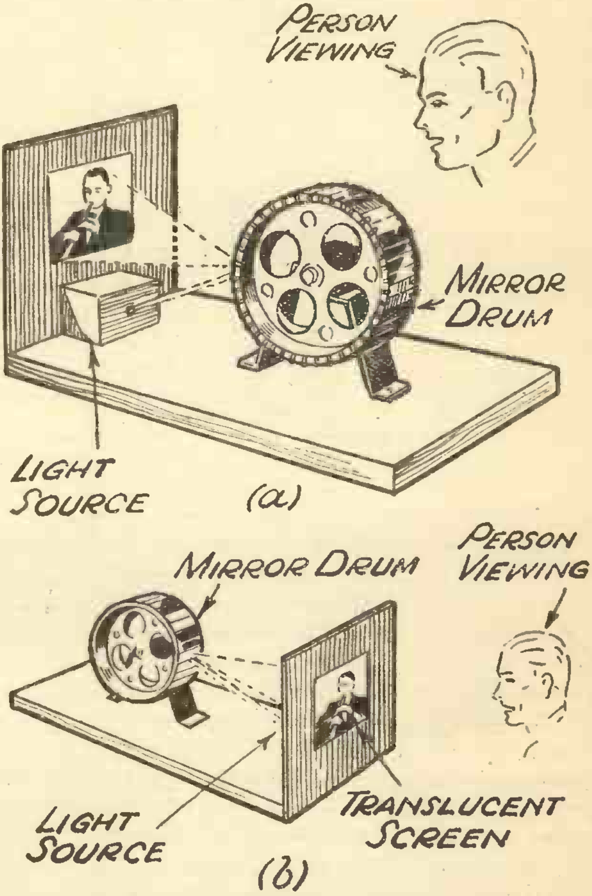


Fig. 66—In (a) an opaque screen is used and the picture is seen by reflected light. In (b) a less powerful light-source is needed since a translucent screen is employed

There is, however, one system which has proved very successful indeed. It employs what is known as the Kerr cell. Like many of the principles used in television, the Kerr cell was discovered by its namesake a long time ago, about 60 years actually.

It has proved a great aid to mechanical television and is used in nearly all modern systems.

How the Kerr Cell Works. To understand the working of the Kerr cell, it is necessary to have some knowledge of polarised light. To many, the subject of polarised light seems rather a fearsome one, like three-phase A.C. working, but it need not be. True it is a very complex subject if delved into deeply, but this is not necessary. A simple knowledge of the main features is all that is required.

A GOOD ANALOGY

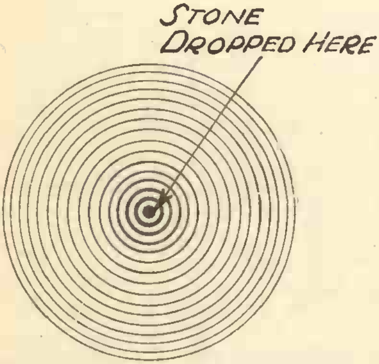


Fig. 67—The waves, spreading in all directions, obtained when a stone is dropped into water, form a good analogy of the way in which light vibrates the ether in all directions

Light is a vibration in the ether, and as you know, ether permeates everywhere and everything. But light is not just a simple to and fro vibration, like a tuning fork for instance. The vibrations take place in all directions at right angles to the direction in which the light is travelling.

For illustrative purposes we will consider a section through a narrow beam of light. The vibrations may be considered as the waves which radiate in all directions when a stone is dropped into a pool of water, see Fig. 67. This, of course, is only a rough analogy, but it happens to serve our purpose admirably.

That is ordinary light. What is polarised light? Look at Fig. 68. Around the point in the pool where we are going to drop our stone again in a minute, we arrange a series of parallel planks with their edges just above the surface.

In goes our stone. But we no longer get the waves radiating in all directions. In the directions A and B they are completely stopped, but in directions C and D they exist between the planks more or less normally.

This little picture we can liken to light waves when they are polarised. They vibrate in one direction only.

To the naked eye polarised light looks just the same as before, but weaker. It is weaker because, as you can see from Fig. 68 a big area of vibration is cut out of the picture.

There are certain substances which when light is passed through them, polarise it in the manner described. Certain crystals such as tourmaline will achieve this. So also will calcite, more commonly known as Iceland Spar.

The latter, however, polarises light in two directions. It allows vibrations in directions at right angles to pass. But these two vibrations have different properties, and it is possible to eliminate one by a further process which leaves us with ordinary polarised light, which is what we want for our next step.

A Marconi development employs both beams, making them eventually coincident, and so producing a saving in light.

Fig. 69 shows the arrangement of a simple Kerr cell. The glass container is filled with nitrobenzine and hermetically sealed.

In it are two metal electrodes A and B. They are flat plates arranged parallel to one another and quite close, and contact with them is made via the two terminals.

The beam of polarised light from our calcite polariser is made to pass between these two plates. If now we apply voltages of suitable value to the two terminals, the effect will be to twist the plane in which the polarised light is vibrating. Now look at Fig. 70(a). Here a beam of light passes into a polariser, which permits, we will say, vibrations only in a vertical plane to pass.

EXPLAINING POLARISATION

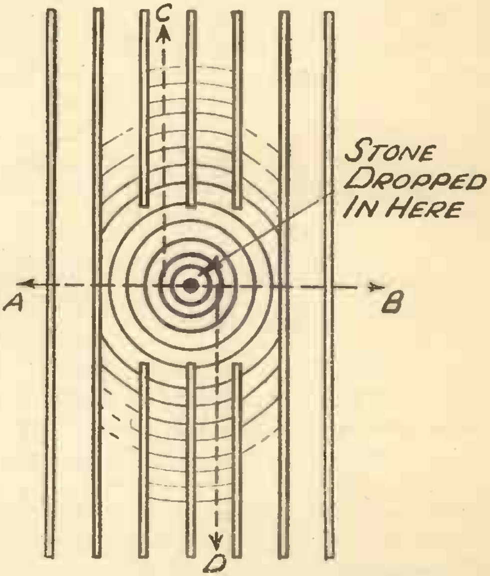


Fig. 68—An ingenious diagram which will help the reader to understand polarised light, in which the ether vibrations are confined to one plane only

The vertically polarised light passes along to the second polariser, which is arranged to pass light in a *horizontal* plane only. The result is that no light at all emerges from the two polarisers.

In Fig. 70(b) we have inserted our Kerr cell between the two polarisers. Until potentials are applied to the

A SIMPLE KERR CELL

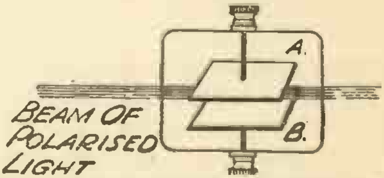


Fig. 69—The simplest form of Kerr cell consists of two parallel plates between which a beam of polarised light is made to pass

plates no difference is noted, but as soon as the potentials cause the vertically polarised light to twist towards a horizontal plane light begins to emerge from the second polariser.

If the plane were twisted until it became horizontal, the full amount of light would be able to pass through. In practice the picture modulations are applied to a suitably biased Kerr cell, and as the voltages fluctuate so more or less light is passed through the system ready for the scanning device whatever it may be.

SHUTTING OFF LIGHT

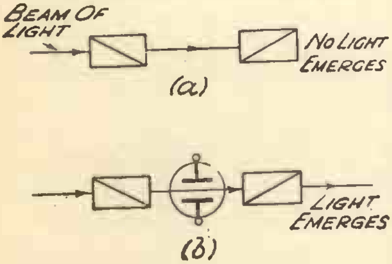


Fig. 70—The object of the Kerr cell is to twist the plane in which light is polarised so that it can pass through two polarising prisms which normally cut off all light

Kerr Cells for High Definition Work. The Kerr cells which have been commonly used for television of recent years have consisted of a number of plates, connected up in banks in the fashion of the multi-plate fixed condenser. These plates are arranged as close together as possible to provide maximum sensitivity and are also parallel.

These cells, however, are of but little use for high definition television in the neighbourhood of 240 lines. The power required to drive them at high frequencies is very great, partly due to their high capacity.

The high capacity has been overcome by a return to the twin plate cell, and the Wright type of diverging plates have proved very helpful. The shape of these plates is seen in Fig. 71.

Another way in which the power required has been usefully reduced is by paying particular attention to the purification of the nitrobenzine used. Special distilling and freezing processes, in which only a portion of the nitrobenzine is retained, are employed to ensure this purity.

DIVERGENT PLATES

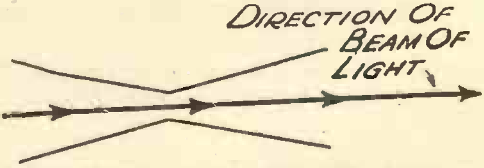


Fig. 71—In order to make Kerr cells suitable for high definition work it has been found necessary to use double-diverging plates, as shown in this diagram

Mirror-drum Viewers. We are now in a position to consider the mirror-drum receiver as a whole. In Fig. 72 is given a diagrammatic sketch of the various stages in the light's progress from source to picture screen, from which you will see how it gradually changes from a steady illuminant to an intelligible picture. The synchronising gear attached to the mirror drum is not shown, but it may be applied in any of the various ways discussed in the previous chapter.

First of all, we start off with a powerful source of light, such as an electric bulb with a concentrated filament. In front of this is a condenser lens A to produce a parallel beam of light. B is an aperture plate and light screen, which passes a narrow beam of light through the first polariser C, the Kerr cell D and the second polarising device E.

The varying light impulses are now focused on to the mirror drum, from which they are finally reflected in such a manner as to scan the picture area on the viewing screen. The mirror drum can be constructed in many ways in practice, but nearly all types have one thing in common, the mirrors are all independently adjustable so that the scanning lines can be adjusted to fall accurately into their proper places on the screen.

A COMPLETE MIRROR-DRUM SCHEME

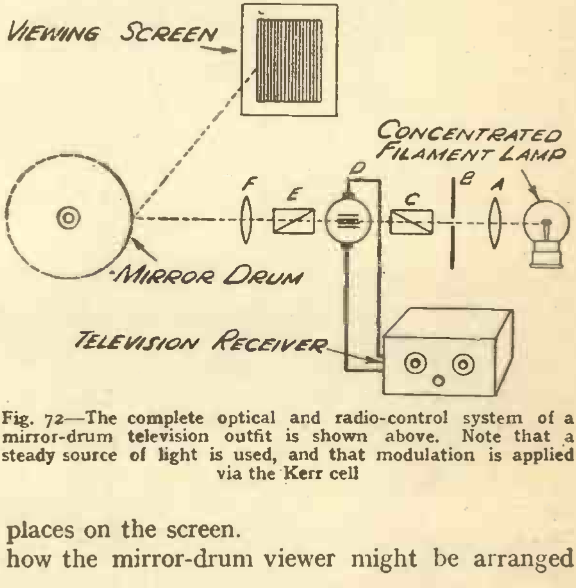


Fig. 72—The complete optical and radio-control system of a mirror-drum television outfit is shown above. Note that a steady source of light is used, and that modulation is applied via the Kerr cell

Fig. 73 shows how the mirror-drum viewer might be arranged in practice.

A modification of the normal mirror-drum system, and which shows considerable promise for the future, is the stationary mirror drum. The development of this is largely due to Mihaly, and it has the great advantage that there is no heavy mirror drum to be rotated. The only moving part is a revolving mirror arranged at a fixed angle.

The diagrammatic sketch of Fig. 74 makes the scheme clear. It will be seen that the mirror takes an "inverted" form. That is to say, the mirrors are arranged round the inside of the drum instead of the outside. They are, of course, all adjustable as in

HOW A MIRROR DRUM VIEWER MIGHT BE ARRANGED IN PRACTICE

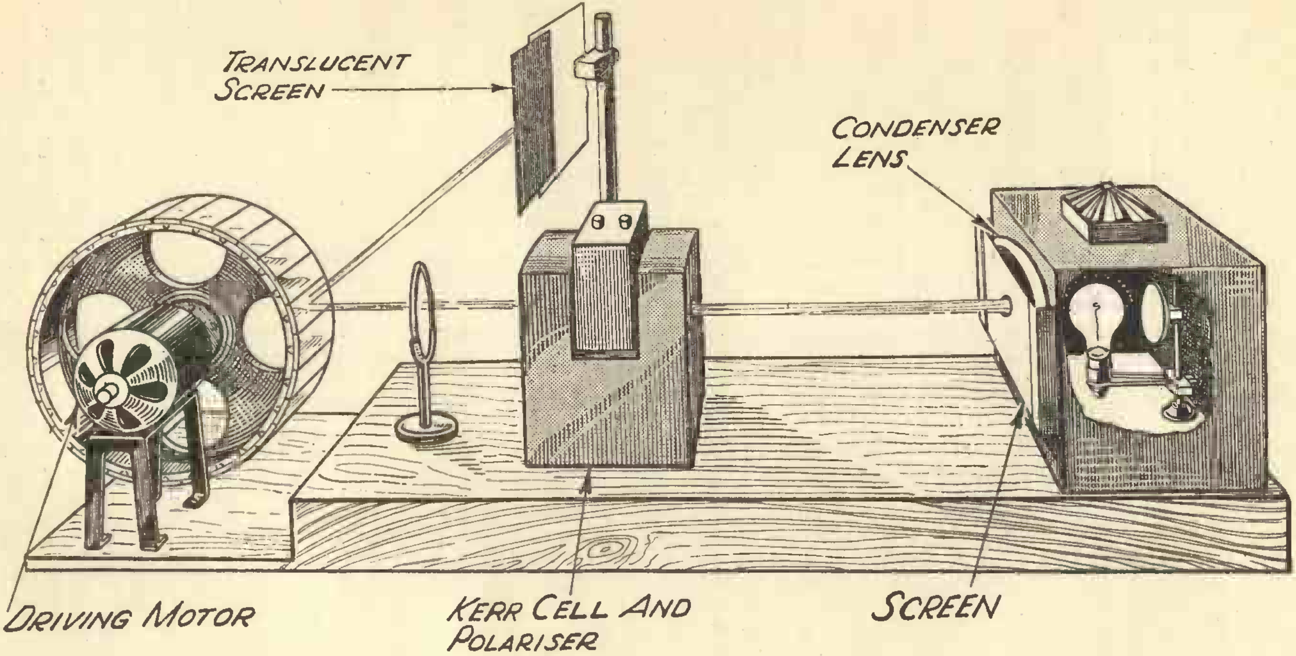


Fig. 73—All the items apart from the receiver, shown in Fig. 72, are included in this practical layout for a mirror drum viewer. The two terminals to which the modulation input would be applied are seen on top of the Kerr cell and polariser unit

the ordinary type of mirror drum, and are all set at slightly different angles.

The light coming from the Kerr cell and polariser unit is first of all reflected from the revolving mirror on to the drum, from which it is reflected on to a different part of the revolving mirror and finally back to the viewing screen.

A PROMISING IDEA

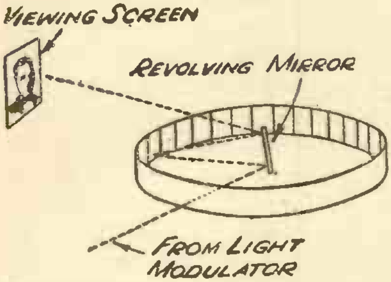


Fig. 74—The great advantage of this stationary mirror drum arrangement is that there is only one small moving part. As can be seen, the mirror drum may well be described as turned inside-out

The double reflection from the revolving mirror is necessary in order that all of the mirrors can be made use of. Without this double reflection only about half of the mirrors could possibly reflect light on to a screen, no matter where it was placed in relation to the mirror drum.

Other Disc Systems. Before going on to more advanced mechanical systems, there are one or two further schemes connected with disc receivers which warrant mention. The first two are merely developments of the simple type of disc receiver fully described in Chapter 8, while the others employ discs of an entirely different nature.

Much conjecture has taken place around the possibility of using an ordinary disc

MECHANICAL INTERLACING

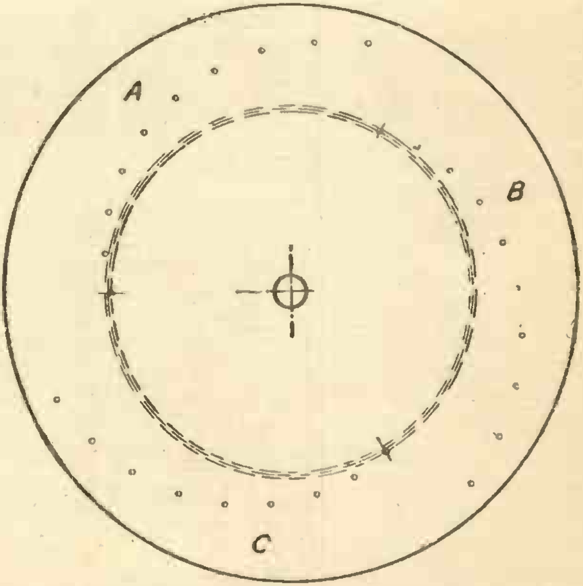


Fig. 75—A modification of the ordinary disc scanner. The holes are arranged in three groups, each group dealing with every third line of the picture

for high definition transmissions. Theoretically there is no reason why it should not be done. One merely requires a spiral with more holes in it, and runs the disc faster in order to get in the increased number of frames or pictures, per second.

But the difficulty of producing mechanically, an accurate disc with say, 240 holes is almost insuperable even if the question of cost is ignored. It has, therefore, been suggested that it should be done photographically.

A very large-scale drawing, several yards across, could be made quite accurately, the positions of the holes being marked by black squares. By using a photographically sensitised transparent plate for the scanning disc, it would be an easy matter to photograph the large scale disc on to it. The holes would appear as little white pin-points on a black background when the disc was eventually developed.

THE LENS DISC

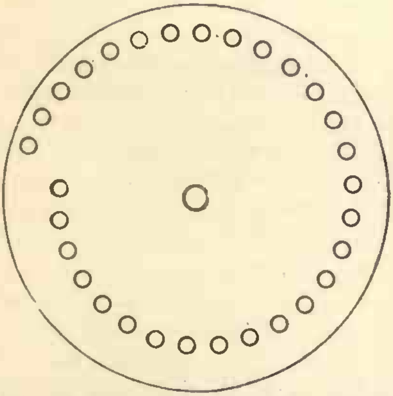


Fig. 76—Very similar to the ordinary scanning disc is this mirror disc in which each tiny hole of the spiral is replaced by a lens, the lenses being arranged in spiral formation

The second scheme is considerably older. It was tried by Sanabria, an American worker. The type of disc used is illustrated in Fig. 75.

For 30-line scanning, instead of having one spiral of 30 holes, there are three of ten holes. Each spiral is arranged to scan every third line. Thus the spiral A will deal with lines 1, 4, 7, and so on; the spiral B will handle lines 2, 5, 8, and so

A LENS DISC VIEWER

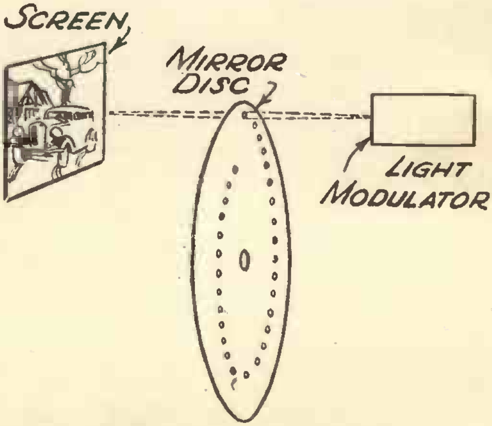


Fig. 77—The advantage of the lens disc over the ordinary one, is that the former passes much more light, and so permits useful projection to be achieved

on, while spiral C covers the remaining ones, namely numbers 3, 6, 9, and so on.

The advantage of the scheme is stated to be that the disc can be run at a third of the speed of a normally arranged disc and yet give the same satisfaction to the eye. Naturally, this scheme would require a special form of transmission to suit it, which is considered very undesirable to-day, when the aim is to have a system of transmission which will suit many forms of reception.

Lens Disc and Jenkins Discs. A method of scanning employing a lens disc has received considerable attention in the past, but it has been used mostly at the transmitter end. Except for the nature of the holes, it is exactly the same in principle as the ordinary disc scanner.

Instead of having a spiral of small holes pierced in the metal disc, a spiral of lenses are fitted in the disc in the manner shown in Fig. 76. So far as the receiver is concerned, this system of scanning is used with a projected picture. It has the advantage that the lenses pass considerably more light than a small hole could. Fig. 77 gives an idea of the light arrangements at the receiver.

The Jenkins system of disc reception is something quite different. Actually it employs two separate discs, and the only real drawback appears to be the difficulty of producing the discs accurately as a commercial proposition.

The discs are made of special glass or quartz, and around the edge, the disc is ground to act as a prism. The angle of the grinding varies continuously around the whole disc. Fig. 78 will help to make this clear. It shows a section through the elevation of the disc and also a sketch of the disc in perspective.

A JENKINS DISC

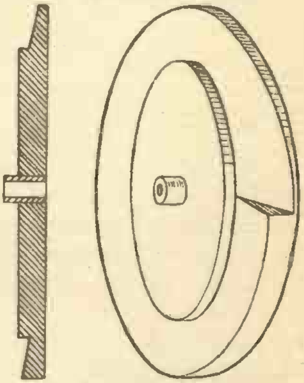


Fig. 78—Made of special glass or quartz the Jenkins disc has a continuously varying angle to its edge, the light beam thus being moved across the screen by refraction

It will be seen that at one part the angle of grinding is actually opposite to the angle at another part, and that there is one point where a sudden change over takes place.

When light is passed through a prism it is bent or deflected out of its previous path. The amount which it is deflected depending on the angle of the prism.

When the beam of light passes through the Jenkins disc it is similarly deflected, the amount depending on which part of the disc is in use. Consequently, if the disc is made to revolve the light will trace a line across a screen placed in its path.

When the change-over point of the disc is reached, the spot on the screen will return suddenly to one end and begin its traverse all over again. Thus we have scanning in one direction.

Scanning in the other is produced by the second disc used in the Jenkins system. The second disc is arranged so that its prismatic action will be at right angles to that of the first.

Fig. 79 shows the correct disposition. The beam of light is passing through the point marked A, and it will be seen that immediately after passing through one disc it has to pass through the second.

FOR COMPLETE SCANNING

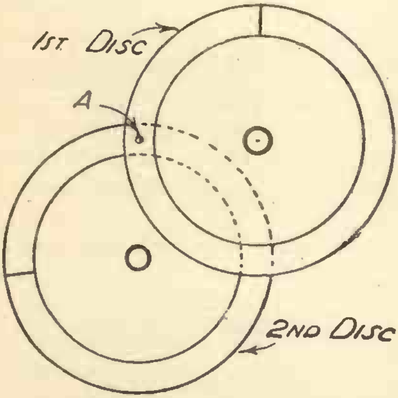


Fig. 79—How two Jenkins discs are arranged to provide complete scanning. The light passes through both discs at the point A, one disc refracting it in a vertical direction and the other in a horizontal direction

The first disc bends the beam of light in a horizontal direction and the second one in a vertical direction. Thus by means of a combination of the two varying prismatic actions the spot of light is made to reach all parts of the picture area on the screen, and scanning is complete.

One disc naturally runs at the speed corresponding to the number of lines per second, and the other revolves more slowly in accordance with

A TYPICAL MIRROR SCREW

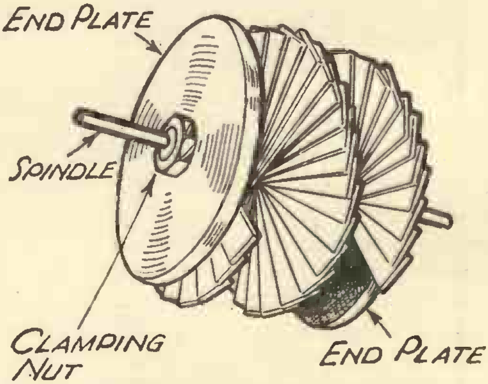


Fig. 80—In the mirror screw, the general arrangement of which is seen here, the edges of metal rectangles are polished to act as reflecting surfaces. The mirror screw is made to revolve as a whole

the number of pictures per second. The correct ratio between the two must of course be maintained, and can be achieved by correct gearing, for instance.

The size, and ratio of length to height, of the picture is dependent on the grinding of the discs. A pictorial representation of the complete set-up for such a television system is given in an art plate. Note that the second polarising prism is called an "analyser," quite a common term for it. The action of this second polariser is, of course, in all such systems, rather to keep out all light except that vibrating in a particular direction than to actually carry out any polarisation.

The Mirror Screw. The mirror-screw system of reception has proved quite popular on 30-line transmissions in this country, and has also been worked on high-definition experiments up to two or three hundred lines. It is one of the most promising mechanical schemes for the future.

A typical mirror screw is illustrated in Fig. 80. It consists of a spiral made up of a number of rectangular pieces of metal, threaded on to a spindle and clamped between two end plates. A "close-up" sketch of three of the plates is given in Fig. 81.

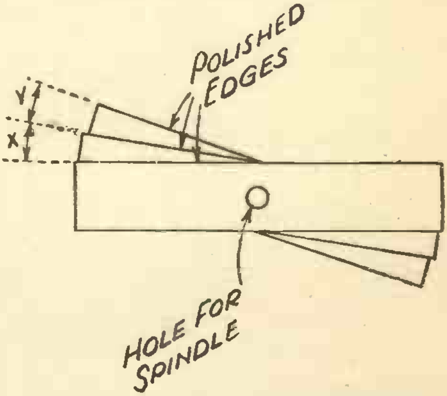

ANGLE OF DISPLACEMENT

Fig. 81—Each mirror of a mirror screw is set at an angle to the next, and these angles (X and Y in this diagram), must all be exactly equal

It will be seen that each one is slightly twisted on the spindle in relation to the one next to it, and that the reflecting surface is one of the long edges of the metal rectangles. The angles x and y, namely the angles made by any two adjacent rectangles with each other must be exactly equal in each case.

There is one mirror, or rectangular piece of metal, for each line in the picture. In the case of 30-line television there would be 30 mirrors, and the angle between each would be 360 degrees divided by 30, namely 12 degrees. In the case of 180 line working, this angle would be 2 degrees.

The width of the picture in the case of a mirror screw is determined by the number and thickness of the mirrors, as shown in

Fig. 82, which shows the screw sideways on. It also shows how a white-line lamp as long as the screw is also required. A suitably shaped line of light controlled by a Kerr cell can, of course, be employed instead of this type of lamp.

As the mirror screw revolves, each mirror reflects a spot of light across the screen as in Fig. 83. The dotted beams of light show the spots from the mirror preceding and the mirror following the one actually seen scanning the screen. If preferred, the disc may be viewed direct without the interposition of a screen.

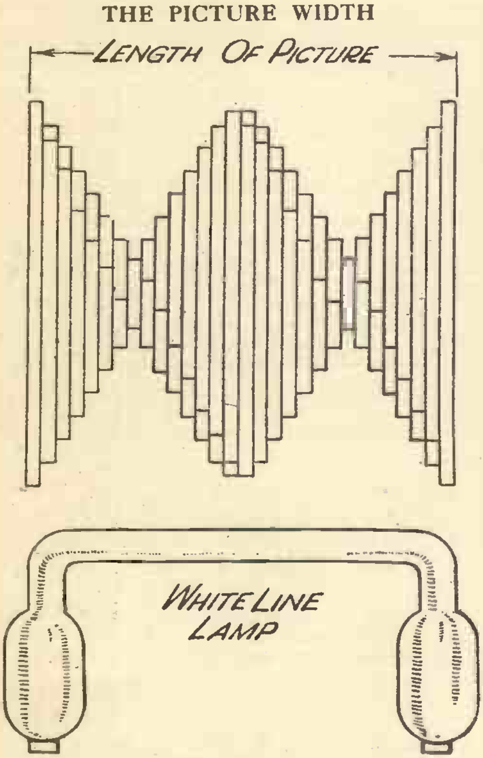


Fig. 82—The width of the picture in a mirror-screw viewer is determined by the length of the complete screw. A source of light as long as the mirror screw is usually employed

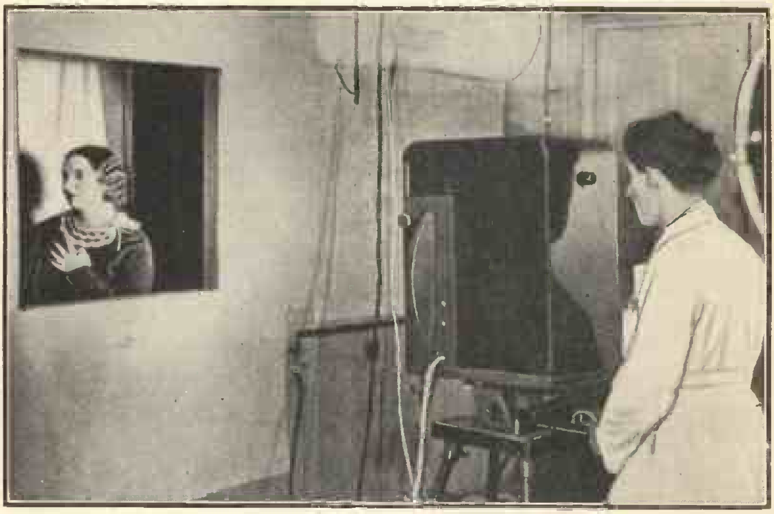
And now we come to an important consideration in mirror-screw viewers. The screen must be placed at the right distance from the screw, otherwise the ratio of length of picture to height will not remain correct.

The reason for this is shown in Fig. 84 where the movement of the spot of light from one mirror is illustrated. The mirror is shown in two different positions, and we will assume that these represent the top and bottom of the picture line (vertical scanning being presumed).

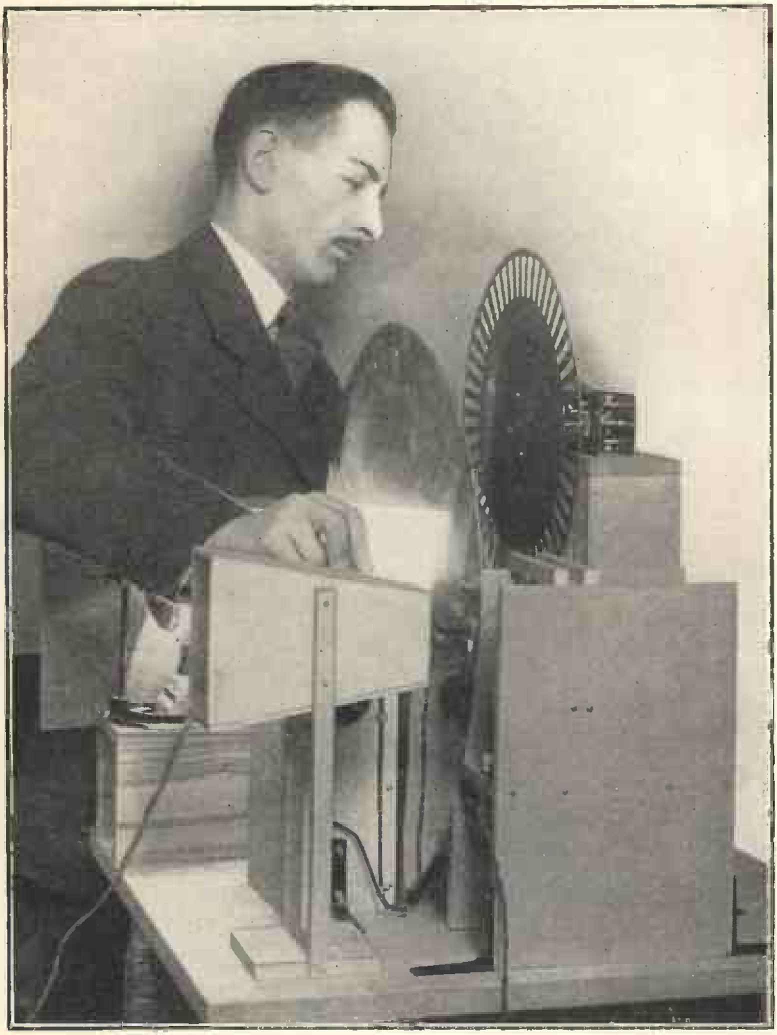
The beam of light for one position is shown as a full line, and for the other as a dotted line. If the screen is placed at S2 the picture will be twice as high as if it is at S1. But the width, it must be remembered, is the same, being controlled by the width of the mirror screw.

This question of screen position is very important when high definition systems are under consideration. If the mirrors are too

THE STUDIO OF THE FIRST TELEVISION STATION TO BE OPENED IN PARIS



TELEVISING A " CLOSE-UP " IN THE STUDIO OF A FRENCH TELEVISION STATION. THE SCANNING AT THE TRANSMITTER OPERATES ON A MECHANICAL PRINCIPLE AND A PART OF THE COVER OF THE SCANNING DISC CAN BE SEEN PROTRUDING FROM THE SIDE OF THE CASE



A COMBINED TRANSMITTING AND RECEIVING APPARATUS FOR 30-LINE EXPERIMENTS

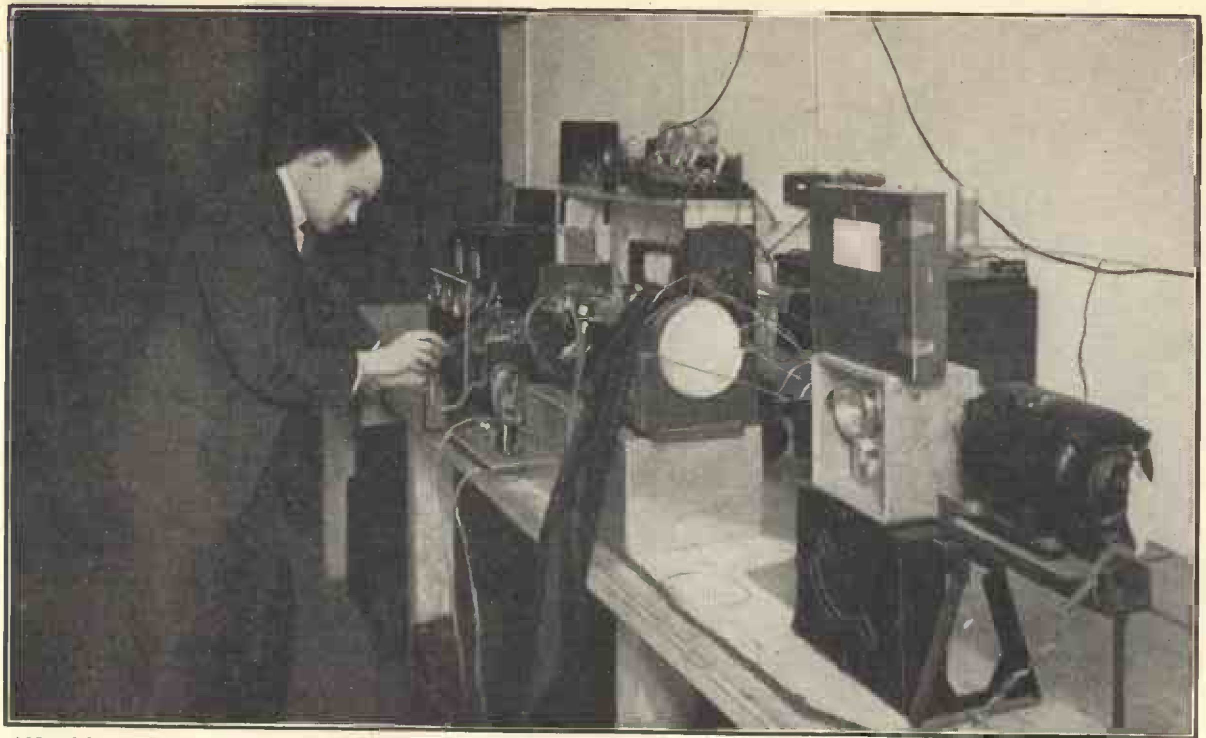
Plate 24

THE EFFECT OF 180-LINE DEFINITION

IT IS VERY DIFFICULT PHOTOGRAPHICALLY TO REPRODUCE ORIGINAL TELEVISION PICTURES ON PAPER AND GIVE A TRUE REPRESENTATION OF THE EFFECT. BUT BY MEANS OF A SPECIAL BLOCK-MAKING PROCESS THE ABOVE PICTURE IS MADE VERY CLOSELY TO APPROXIMATE 180 LINE RECEPTION. THIS IS THE DEGREE OF DEFINITION THAT WAS EMPLOYED IN THE EARLIER BAIRD EXPERIMENTAL HIGH DEFINITION TRANSMISSIONS FROM THE CRYSTAL PALACE. EVEN FINER DEFINITIONS HAVE BEEN ADOPTED FOR THE B.B.C. TELEVISION SERVICE, THE BAIRD TRANSMITTER GIVING 240 LINES AND 25 PICTURES PER SECOND AND THE MARCONI—E.M.I. 405 LINES (INTERLACED SCANNING) AND 50 FRAMES

Plate 25

Plate 26

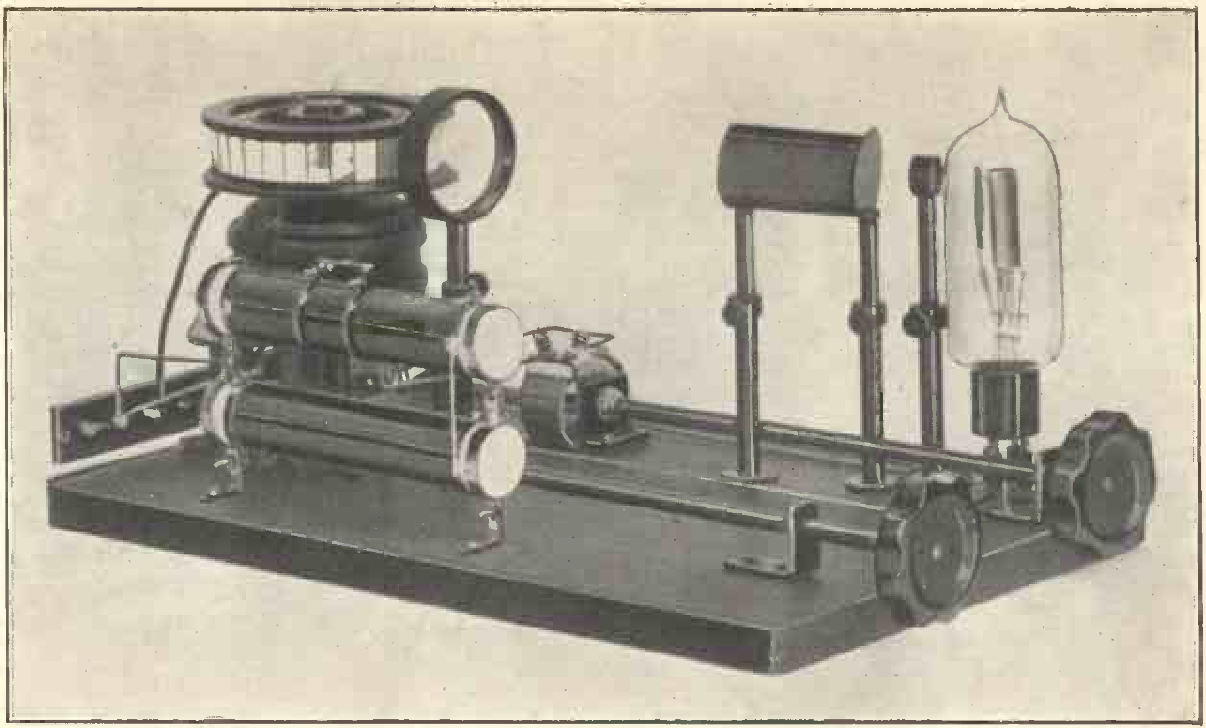


AN APPARATUS USED BY BAIRD TELEVISION FOR RECORDING RECEIVED TELEVISION PICTURES ON FILMS SO THAT THEY CAN SUBSEQUENTLY BE PROJECTED IN CINEMA THEATRES

TELEVISION WITHOUT THE AID OF VISIBLE LIGHTING. BAIRD AND AN APPARATUS EMPLOYING INFRA-RED RAYS WHICH HE DEMONSTRATED MANY YEARS AGO

Plate 27

Plate 28



AN INTERESTING EXAMPLE OF EARLY MIRROR-DRUM PRACTICE IS TO BE SEEN IN THIS GERMAN LOW DEFINITION VIEWER close together, namely very thin, the eye will be unable to distinguish properly from one line and the next, and the expected increase of definition will not be achieved unless the screen is brought much nearer. But this will upset the picture ratio in the manner already described.

PRACTICAL DISPOSITION OF PARTS

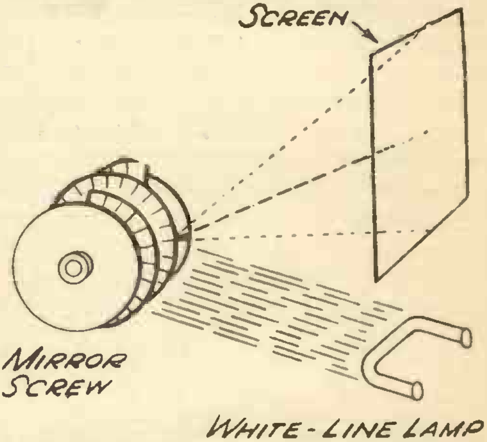


Fig. 83—The relative disposition of the light source, screw and viewing-screen of a mirror-screw viewer are given in this diagram

To overcome this a double drum has been introduced on which there are two mirrors capable of reflecting a spot on to the screen at any given moment. Only one of these is wanted, however, so a shutter is arranged to blanket off the light from the other at the desired time. Due to the double effect the drum has to rotate at double the normal speed, that is to say for 25 pictures per second it has to make 50 revolutions.

Another suggested way of reducing the viewing distance without upsetting the picture-size ratio, is to employ mirrors with a curved reflecting edge. The mirror edge curves outwards in the middle, thus giving a wider angle of light variation.

VIEWING DISTANCE

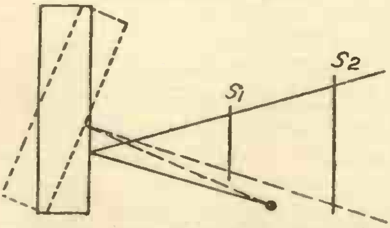


Fig. 84—Since the width of the picture in a mirror-screw viewer is fixed as explained in Fig. 82, there will be a certain correct distance away for the viewing screen if the picture proportions are to remain correct

Scophony. The Scophony system of television is a comparatively new one about which there has been considerable misunderstanding so far as its principles of operation are concerned. This, no doubt, is largely due to the quite different ideas concerned.

It certainly appears to have considerable possibilities, although the basic principle is remarkably simple. It may be explained in the following way.

In Fig. 85 is shown a complete "picture" in the form of a number of differently shaded lines. Actually this could be any subject to be televised, the form shown merely being adopted to assist the explanation.

Before this "picture" is scanned, it is presented to a special device, which splits it up into a number of strips, and arranges these strips end to end in the manner illustrated. The greater the number of strips, the higher the definition obtained.

The scanner simply has to traverse the strip once, in one direction, for each complete picture. The scanning is thus considerably simplified.

At the receiver the exact opposite takes place. A strip of modulated light is presented to the special device, which cuts it up into strips and arranges these side by side in their right order, thus building up the desired picture.

The "special device" is known as a prismatic echelon. It consists of a number of thin prismatic formations arranged side by side and displaced slightly in relation to one another. In actual practice this echelon is arranged to rotate.

THE PRINCIPLE OF SCOPHONY

Fig. 85—This diagram shows how the picture is split up into a straight line before scanning in the Scophony principle of television, which calls for scanning in one direction only

Mirror Drum Variations. Much has been talked, and considerably more thought, about the possibilities of converting present 30-line television apparatus for high-definition work. As a general rule there is little possibility of any success in this connection, but one scheme has been suggested which is of great interest to those who have a 30-line mirror-drum outfit.

The arrangement is outlined in Fig. 86. Briefly, the idea is to make each mirror produce eight lines on the picture screen. This is achieved by means of the line-multiplier seen to the right of the mirror drum.

First of all there are six prisms across which each of the 30 mirrors causes the spot of light to pass. Each of these prisms deflects the spot back to the beginning of the scanned area and so makes six lines out of one.

But so far these six lines will all be on top of one another. This is where the six glass plates next to the prisms come in. Each of these displaces the beam just the width of one scanning line.

Thus each mirror on the drum produces six lines on the screen. And by simple multiplication we obtain 180 lines. To obtain 25 pictures per second instead of 12½ the drum has to rotate at twice its normal speed. Eight prisms could be used to produce 240-line scanning.

In many cases existing motors could be made to turn at twice the speed. And, of course, it would be necessary to arrange the drum in a horizontal plane to obtain horizontal scanning.

LINE MULTIPLYING

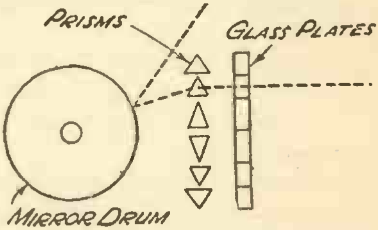


Fig. 86—By an optical system of prisms and refracting plates, each line produced by a mirror drum can be split up into a number of lines

One of the biggest problems in the application of the mirror drum to high-definition television is that of canting the mirrors in relation to one another. The provision of 180 or 240 mirrors on a drum of reasonable proportions is not an easy matter, either.

Fig. 87 shows a suggested method of overcoming these problems, in which two mirror drums are employed, one taking care of horizontal scanning and the other handling vertical scanning. The vertical drum would simply have 25 mirrors and revolve at 60 revolutions per minute, thus producing the necessary 25 pictures per second.

This drum would cause the light beam to strike each mirror on the second drum at a slightly different angle, thus obviating the biggest difficulty of canting the mirrors. But since there is no canting of the mirrors to be carried out on the horizontal drum their number can be altered to any desired figure.

USE OF TWO DRUMS

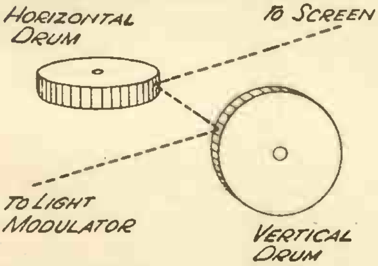


Fig. 87—By using separate mirror drums for horizontal and vertical scanning, the difficulty of using a large number of mirrors for high-definition work can be overcome. The drums are arranged at right angles, as illustrated in this diagram

All that a reduction of the number of mirrors means is that the drum must revolve quicker in order to produce the desired number of lines. If there were 240 mirrors, this drum would have to revolve at 25 times per second. If there were 120 mirrors it would have to do 50 revolutions per second.

Fifty revolutions per second mean 3000 per minute—a high figure, but by no means impracticable. Remember, plenty of light-car engines will do even 5000 revolutions per minute quite comfortably. A good heavy motor, with well-balanced parts and ball bearings, should be able to tackle the job quite satisfactorily.

Vibrating Mirrors. The use of vibrating mirrors for television is almost as old as the Nipkow disc itself, but modern variations show considerable improvement over the earlier attempts. The basic principle, however, remains unaltered, and can be made perfectly clear by the illustration of Fig. 88.

SCANNING BY MEANS OF VIBRATING MIRRORS

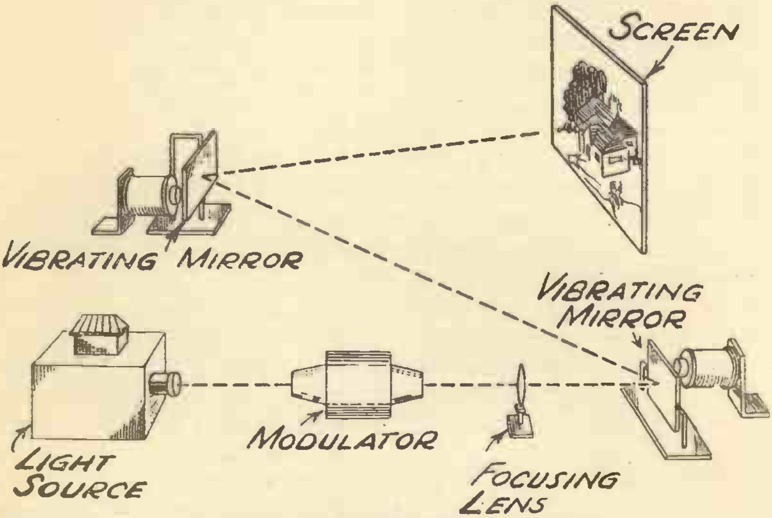


Fig. 88—The two mirrors which reflect the modulated beam of light one after the other are arranged to vibrate in directions at right angles to one another, thus producing complete scanning of the picture

There is a marked similarity to the double-drum system just described. The mirrors vibrate in planes at right angles to one another, one taking care of vertical scanning and the other of horizontal scanning.

The mirrors are arranged on swivelling axes passing down their middle, and are made to vibrate backwards and forwards by electromagnets controlled by pulses of current occurring at the right frequencies. These pulses can be locally generated and controlled by the synchronising signals in the methods described in Chapter 9.

In Fig. 88 it will be seen that the modulated light passes first to the horizontal mirror, which moves it backwards and forwards in a vertical direction, these vertical movements then being given a horizontal component by the second mirror, which is pivoted vertically. Thus the complete scanning movements are achieved by the time the beam of light reaches the screen.

The Priess system of television is demonstrative of what is being done with vibrating mirrors under modern conditions. Its distinctive feature is that only one mirror is employed, this being made to oscillate in two directions.

The mirror itself is mounted on a thin steel wire on which it is caused to swivel by an electro-magnet. A frame holding the steel wire at its ends takes care of the slower movements in the opposite direction.

Very small power is needed to move the mirror in its two directions, because the natural frequencies of the mechanical arrangements are arranged to be exactly that of the desired speeds of vibration. It is claimed that so small is the driving power needed, that it can be obtained direct by amplification of the synchronising frequencies.

Special transmitting systems are needed for oscillating mirrors because each alternate line is scanned in the opposite direction, an instantaneous fly-back to enable all scanning to be in the same direction not being obtainable.

There remains but one other system to be mentioned to make this chapter complete. It is really of only academic interest, but is worth describing because of its similarity to the function of the human eye, and because it brings home in such a definite manner the first requirement of any television system, namely, to build up the complete picture by means of individual light and dark points.

OF HISTORIC INTEREST

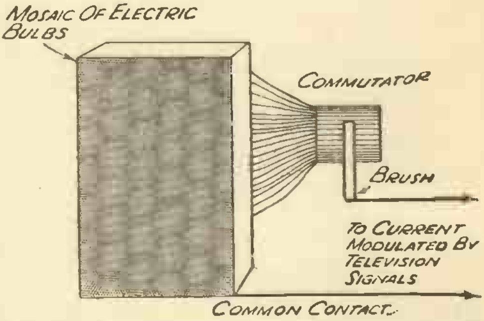


Fig. 89—If this method of television were not severely limited by mechanical considerations, it would come nearer than any to giving us perfect television on large screens

It was used in some of the earlier Baird experiments in the obtaining of large-size pictures. The receiver is illustrated in

Fig. 89, and consists mainly of a large frame containing many hundreds of little electric bulbs.

Each bulb is individually connected to one segment of a commutator, which connects them one after the other to the modulated source of power controlled by the television receiver.

The commutator is arranged to be in synchronism with a commutator at the transmitter, which has the same number of segments. But in this case the frame of bulbs is replaced by a similar frame containing many hundreds of photo-electric cells.

When the top right-hand photo-electric cell is put into circuit by the commutator at the transmitter, the top right-hand bulb is also put into circuit by the commutator at the receiver. And according to the amount of light falling on the photo-electric cell, so the brilliance of the electric bulb varies. This process is carried out for each cell and bulb in the mosaic, the number of times per second the whole mosaic is covered giving the number of frames per second.

A. S. C.

Chapter 11

BRIGHTNESS OF TELEVISION PICTURES

REMARKABLE STRUCTURE OF THE EYE—FIVE MILLION LIGHT-RECEIVING ELEMENTS—DEFINING DETAIL LIMITS—CANDLE-POWER—THE "FOOT-CANDLE"—THE MEANING OF "LUMEN"—WHAT IS CONTRAST?—GRADATION RATIOS—FECHNER'S LAW—DAYLIGHT AND ARTIFICIAL LIGHT INTENSITIES—THE "PHOTON"—SEEING DETAIL IN DAYLIGHT—ACTION OF THE IRIS—THE MOTION OF TELEVISION IMAGES—THE SIZE OF THE PICTURES—APPARENT BRIGHTNESS—THE QUESTION OF COLOUR.

Of all the many practical problems associated with present-day television those concerning the production of televised images having a satisfactory standard of brilliancy and illumination are, so far as the television set owner is concerned, the most outstanding. A system of television transmission and reception may have been perfected down to the utmost detail in all matters respecting the electrical working and synchronisation of the system. Nevertheless, if the pictures which such a television system produces at the receiving end do not conform at least to a reasonably comfortable standard of brightness, then that television reception system is a dead one and will never be accorded public favour. Wireless broadcasting would never in its earlier days have attained its phenomenal success if listeners had found it necessary to strain their ears in order to catch faint whispers coming from imperfectly designed sets. So, also, the ordinary individual will never enjoy television reception if he finds that eye-strain is a necessary accompaniment to the viewing of televised images.

Whilst, in this chapter, we do not propose to concern ourselves with the various electrical methods which are being adopted for the purpose of increasing the brightness of televised images, we imagine that all readers will welcome a general survey of the subject of illumination, light-intensities and of the reaction of the human eye to various conditions of lighting, for, having a thorough grasp of these fundamental matters, the reader will then easily appreciate the various exacting conditions which have to be satisfied by the television set designer before the eye will accept the televised image as being one of satisfactory standard.

The human eye, it is well known, is far less accommodating than the human ear. The ear will put up with, and will even find pleasure in, very poor sound reproduction. It will, in fact, actually add, as it were, the missing elements of the sound reproduction. Not so the eye, however. That organ of our bodies is a stickler for accuracy. The eye is never satisfied with poor reproductions, and it refuses to make up for deficiencies in the strength or balance of illumination.

HOW WE SEE

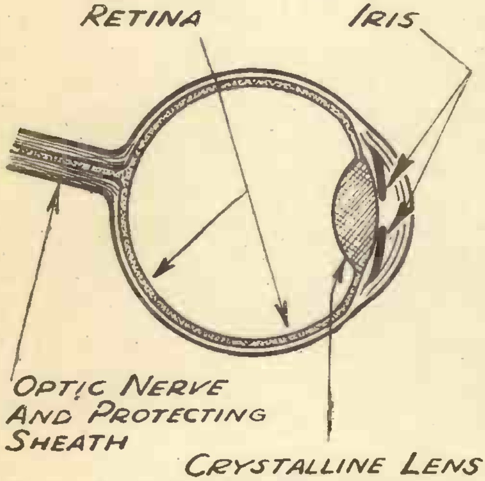


Fig. 90—The principal features of the construction of the human eye

Five Million Light-receiving Elements. Let us, for a moment, briefly run over the structure of the eye. It is a remarkably efficient and foolproof organ, a miniature self-recording camera, in fact, having its crystalline lens, its iris diaphragm, and its recording surface—the retina—from which the light impressions are transmitted along the optic nerve up to the visual centre in the brain (Fig. 90). The retina of the eye possesses a truly remarkable structure. It contains, closely bunched together all over its surface, approximately five million light-receiving elements. Some of these elements are conical in formation, others are rod-shaped. They constitute the " rods and cones " about which so much is heard nowadays. Over the rods and cones flows a chemical dye which is known as *rhodopsin*, or " visual purple." This purple dyestuff is bleached by the action of light, and to an extent proportional to the intensity of the light. The bleached or partially-bleached visual purple excites the rods and cones—remember, there are five million of them—and from these elements varying nerve impulses are sent up to the brain. How these impulses are translated into our sensation of light is not known. All we know is the mechanism of their origin in the retina of the eye.

The rods and cones are not evenly distributed in the retina. The centre of the retina contains almost exclusively cones. As, however, the outer boundaries of the retina are approached, rods make their appearance in increasing numbers until at the extremities of the retina the number of rods is much greater than the number of cones.

It is found that, under normal illuminations, it is the cones which do the business of collecting light impressions and transmitting them to the brain. The rods are merely reserve elements. Their function is to deal with illuminations of low intensity.

Defining Detail Limits. Owing to the fact that human vision is due to the functioning of some five million separate and distinct picture elements—the rods and cones—it is obvious that the images which we see in our everyday life are not entirely grainless ones. The images are made up of some five million points, and the distance apart of these minute points defines the limits of detail which the eye can perceive.

You will remember that the cones—the picture-receiving elements of the eye—are most thickly congregated at the centre of the retina, that is at the portion of the retina directly at the back of the eye. These elements function under normal and strong illumination intensities. That is why we are able to perceive minute detail under good illumination. When it comes to poor illumination, however, matters are far different. The eye cannot possibly perceive the same detail under poor illumination as it can under normal lighting because not only are the rods—the retinal elements concerned with light-reception under poor illuminations—situated at the sides of the retina, but they are also spaced much farther apart from one another than are the cones. It is on account of this fact that we instinctively tend to bring any poorly illuminated object into the centre of our vision in order to distinguish as much detail as possible. But here, the eye defeats its own object, for the centre of the retina, as we have already seen, only deals with normal and strong illuminations. Thus, usually, a state of semi-confusion is set up and the eye sees, under poor illuminations, a detail-less blur, faintly-lighted and hazily-outlined. That is what the earliest television pictures were like. Nowadays, of course, they are enormously improved upon that poor standard.

Candle Power. Before continuing with matters pertaining to the reaction of our eyes to varying degrees of illumination, let us deal now with some matters connected with the standards of brightness itself. As you know the oldest standard of lighting is the candle-power, which, as its name implies, is the intensity of light emitted by the burning of a standard candle.

The British standard candle-power represents the light emitted from a candle which burns approximately 120 grains of spermaceti per hour, the height of the flame being about 45 millimetres. Not a very satisfactory standard of illumination, not only in view of its intrinsic nature, but also on account of the fact that there are several other similar light-standards in use.

LIGHT MEASUREMENT

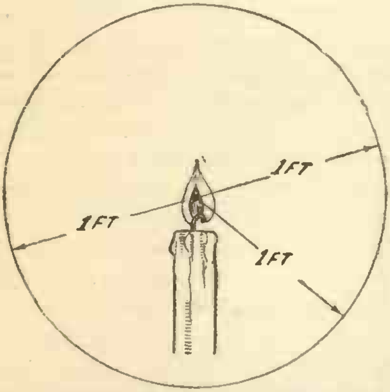


Fig. 91—This illustrates the illumination-standard known as the foot-candle. It is the intensity of illumination received at a distance of one foot from a standard candle

The "Foot-candle." A rather better illumination-standard is the "foot-candle," which is the intensity of illumination received at a distance of one foot from a standard candle (Fig. 91). Such an illumination-standard is frequently used in connection with television images. The illumination derived from a candle placed at a distance of one metre is, similarly, known as the "metre-candle," or the "lux." From this standard we derive the "millilux" and the "microlux," signifying a thousandth and a millionth of a lux or metre-candle respectively. These prefixes will be familiar to you in milliampere and microampere.

The Meaning of "Lumen." You may, also, have come across the term "lumen" used in connection with light intensities. This standard is used more particularly in assessing the brightness of illumination which falls on to the sensitive surface of a photo-electric cell. It is seldom employed for television receiving-screen illumination measurements. The lumen, in reality, represents the quantity of light shed all around it by any given light-source. As an example, a lamp of one candle-power gives off 4π lumens of light, the symbol π being a mathematical constant and equal to 22/7.

What is Contrast ? The brilliance of a televised image is a function of its brightness. A brilliant image is a bright one, but, more than that, it is an image which has a long scale of clearly-defined tones, ranging from the "high-lights" or whitest whites down to the deepest blacks. This is the standard at which all television systems should aim. What we term "contrast" in images is the ratio or difference between the varying depths of tones which make up the picture. There would be little contrast, for instance, in a televised image of a black hat displayed against a black background. If, however, the black hat were disported in front of a white background, it would be readily receivable, for in such an instance, a maximum amount of contrast would be present in the picture. Contrast makes for clearness in a televised image. Without contrast, images are flat and lifeless. It is in order to ensure that adequate contrast is available and, also, in many instances, actually to accentuate this very desirable quality that television artistes subject themselves to special make-ups, so that their features are rendered "strong" and easily picked up by the scanning beam of the television transmitter. Generally speaking, the more contrasty an object is, the more easily it is televised and the more clearly it will be defined upon the receiving screen of the television apparatus (Fig. 92).

CONTRAST IS NECESSARY FOR CLEARNESS

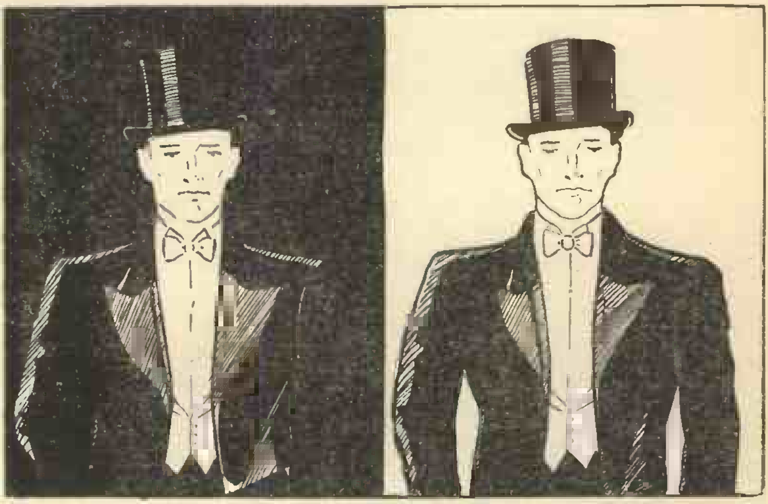


Fig. 92—The least contrast is given when a black object is displayed against a black background and the greatest with a black object against a white background

Gradation Ratios. The human eye can detect a very great range of differences between varying tones in an image, it being estimated that the ratio of light and shade in an image, seen in good daylight, is about 50,000 to 1, This range of light and shade is usually termed the "gradation" of the image. A good photograph possesses a gradation ratio of more than 100 to 1, whilst a first-class cinema film has a gradation ratio of about 60 to 1. Nobody quarrels with the gradation and contrast of the average projected cinema film and if the gradation of a televised image could be made equal to this, all would be well. The gradation of a televised image possesses often less than half this ratio. It is found in practice, however, that the eye will put up with this diminution in gradation ratio without much complaint provided always that the high-lights or bright areas of the picture are left intact and that no detail is sacrificed in these areas.

Fechner's Law. What is known as *Fechner's law* applies to televised images in much the same manner as it does elsewhere. Fechner's law, in a nutshell, states that for each addition of brightness to an illumined surface you have to increase more than proportionately the intensity of the illuminating source. For instance, if you require to double the apparent illumination-intensity of your television screen, you will find it necessary to more than double the illumination-intensity of your neon lamp or of whatever other light-source you may be using. This Fechner's law is a very important factor to bear in mind when considering light-intensities and illuminations, and it is constantly cropping up in relation to such problems.

Daylight and Artificial Light Intensities. The intensity of normal daylight illumination is very variable. On an average, however, at its brightest it is of the order of 2,000 foot-candles. Poor daylight illumination may possess an intensity of merely 20 foot-candles. Under an artificial illumination of about 3 or 3.5 foot-candles intensity we can read comfortably and for considerable periods without becoming tired. The average illumination-intensity of a home cinema screen is about 8 foot-candles. In all but the best of television-receiving screens, however, there is an illumination intensity of not much more than 0.15 foot-candle. It is for this reason that all possible attempts are made to conserve every scrap of light in a home televisor and to make the best possible use of it. In course of time, the illumination efficiency of the home television receiver will increase very considerably, but, so far as present television receiving methods are concerned, the above is a pretty accurate estimate of the illumination-intensities which are obtained in them.

The "Photon." In connection with screen illumination intensities a special standard of light measurement has been evolved. This is the "photon," one photon being a measure of the intensity of light falling upon the retina of the human eye, when the pupil of the eye has an aperture of 1 sq. millimetre and when the object viewed has an illumination intensity of 1 foot-candle. It is found that the amount of light entering the eye from the screen of a television receiver approximates to some 15 photons.

Seeing Detail in Daylight. The visual acuity of the eye, or, in other words, its power of distinguishing detail, is influenced not only by the actual brightness of the televised image, but also by its motion and—note this carefully—by its size. Any reader of this article who happens to be an amateur photographer knows that, within limits, the more he " stops down " or closes the diaphragm or aperture of his camera lens, the sharper and more detailed will be the image on the plate. This is because light rays proceeding through a narrow aperture are more accurately and completely focused than they are when passing through a wide aperture.

Action of the Iris. Much the same conditions govern the functioning of the light-focusing mechanism of the eye. In this organ, the iris contracts or expands in front of the crystalline lens, the movement of the iris being quite involuntary and being operated automatically by the intensity of the light. In bright light, the iris diaphragm of the eye contracts in order that the retina may not be too powerfully illumined and thereby harmed. In contracting, the iris forms a narrow aperture for the light rays to pass through to the retina at the back of the eye. This results in a sharpening up of the image thrown on the retina. Consequently, we see, usually, the clearest detail in bright light.

When, however, on the other hand, the eye is poorly illumined, as, relatively speaking, it is when viewing televised images, the iris diaphragm opens up to its maximum extent in order to allow as much light as possible to pass through it to the retina. In doing so, however, it tends to take away from the eye the power of seeing fine detail, for the light rays entering the eye cannot be focused completely by the wide-open iris. Thus, in this one respect alone, there is a definite limit to the amount of detail which can be perceived in a televised image, that limitation being due to the low intensity of its illumination. (We except, however, the more advanced and expensive instruments.)

The Motion of Television Images. The motion of a televised image has an effect upon its detail and upon the clearness with which it can be seen. Under operating conditions, it is found that even the smallest degree of movement improves the televised image very considerably. This effect is due, most probably, to the slight non-coincidence of the successive pictures which make up the televised image. Much of the " grain " of the image is eliminated and the detail of the picture is cleared up surprisingly. The same effect obtains, also, in the case of an ordinary cinema film, the detail on the screen being less sharp when the film is stationary in the projector than when it is in motion in the normal manner.

The Size of the Pictures. Then there is the actual size of the televised image to take into account when reviewing the detail and contrast characteristics of televised images. Surprising as it may seem, the dimensions of the image-screen of a televisor exert an appreciable effect upon the clarity with which the image can be viewed. It is found that the facility with which the eye is able to deal with differences of light and shade and of tone values generally is considerably lowered by a diminution of the size of the screen upon which the image appears. Especially under conditions of low-intensity illumination does this effect show itself. Hence, the general tendency in television-receiver design is not merely to increase the illumination intensity of the received images, but, also, within limits, to increase the size of the screen (Fig. 93). The first television images were little bigger than a postage stamp. Subsequently they reached cigarette-card size. Recently, a cathode-ray tube giving a one-foot-square picture has been designed and, without a doubt, these dimensions of the available field of vision

SIZE AFFECTS THE CLEARNESS

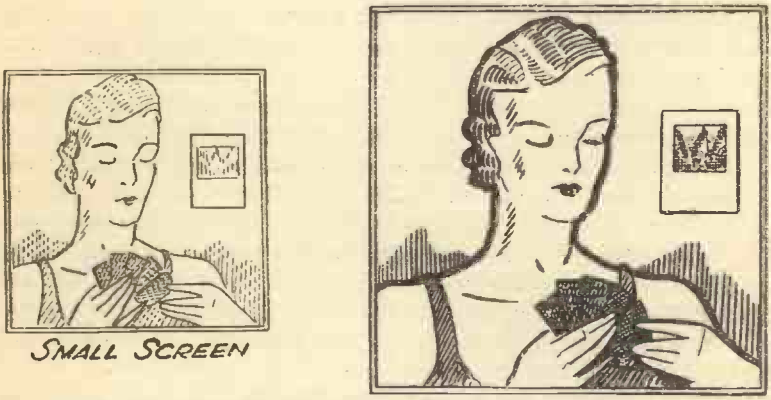


Fig. 93—The same image has been drawn clearer on the larger screen in order to illustrate the law of the larger screen giving the clearer image

will be increased progressively as television technique and receiver designs advance.

Apparent Brightness. The brightness of a televised image, or, at least, the apparent brightness of the image depends a good deal on the conditions under which it is viewed. If you take a television receiver out into full sunlight and attempt to view the received image under such conditions you will have to expect almost complete failure. This is because the sunlight is so many thousand times more intense than the televised image illumination. Under the influence of strong light, the iris of the eye contracts to almost a mere point. It cannot, therefore, deal with any light rays other than those of great intensity which have thus caused it to contract.

For the most favourable viewing of a televised image, all interfering light, both natural and artificial, must be cut out. It is for this reason that in the older television receivers, the image screen was secured at the end of a "tunnel," the sides of which acted as a sort of hood or shade, and so cut off a good deal of extraneous and interfering light.

Even under the best operating conditions, of course, a televised image can never appear bright and clear to an individual who has just walked out of the daylight into a shaded or artificially-lighted room. In order to appreciate a televised image at its best, the eye requires time to accommodate itself to the fairly dim illumination under which the television receiver should be operated. During this process of accommodation—a process lasting, ordinarily, about ten minutes or a quarter of an hour—the iris of the eye dilates and remains in that condition, thus enabling more light rays to pass through it to the retina. As this accommodation takes place, the televised image will be noticed to grow brighter and brighter and also to increase in clarity and contrast.

The Question of Colour. The characteristic orange or orange-pink colour of televised images set up on the screen by means of a neon lamp alone is by no means the most favourable shade of image for clear viewing. As the colour of an object or image becomes more and more red, the eye becomes less sensitive to it. The human eye is most sensitive to one particular band of the spectrum, which manifests itself in the form of light of a peculiar bluish-green. Televised images in this colour, even if they could be obtained (and, at present, they cannot be so produced) would not be very desirable. The very close approximation to white light given by some types of cathode-ray tubes give by far the most satisfactory type and colour of television image.

Natural colour television, as would be expected, is proving as formidable and as complicated a problem as that of photography in natural colours. The coming of colour television will, if anything, tend to complicate the problems associated with the production of received images of satisfactory brilliancy, for not only will the illumination sources of the receiver have to be increased very greatly in intensity, but, also, a correct balance will have to be maintained between the various colours on the screen, otherwise the eye, more sensitive to one colour than it is to another, will, by picking out its most easily perceived shade, concentrate upon the one hue to the almost total exclusion of the other.

Brother Eye is, without a doubt, our good, faithful, and truly indispensable friend. But, as we remarked at the commencement of these notes, he is apt to be a most exacting fellow, and, decidedly, he will not put up with the various imitations and impositions which are frequently foisted upon that other lifelong companion of ours—Brother Ear. It is, therefore, as we have seen, in attempts to comply with the exacting conditions laid down by the eye for the obtaining of clear and comfortable vision that many of the best-known workers in the television world are at present engaged.

J. F. S.

Chapter 12

THE CATHODE-RAY TUBE

THE SIMPLEST FORM—GENERAL FORM FOR TELEVISION PURPOSES—NATURE OF CATHODE RAYS—THE "GUN"—TRACING THE SCREEN—THE DEFLECTOR PLATES—MAKING THE BEAM SCAN THE SCREEN—SYNCHRONISING IMPULSES—BRIGHTNESS OF THE SPOT ON THE SCREEN—THE COLOUR OF THE RECEIVED PICTURE—TUBE SENSITIVITY—FOCUSING TO A SHARP PICTURE—THE NEGATIVE SHIELD—GAS FOCUSING—"HARD" TUBES—MAGNETIC DEFLECTION—POWER SUPPLIES—FATIGUE AND WEARING-OUT OF THE FLUORESCENT SCREEN—THE LIFE OF THE TUBE

Mechanical systems of television have been fully discussed in the foregoing chapters, and now we come to what are known as the electrical systems. These systems are based upon the use of the cathode-ray tube, and so it is essential for us to have a knowledge of the construction and principles of operation of this important device. You will realise its importance from the fact that many experts consider that the future developments of television lie entirely in the direction of cathode-ray transmission and reception.

The Simplest Form. In its simplest form the cathode tube consists of a glass bulb, practically evacuated of gas, a high electrical potential difference being applied across a pair of metal electrodes sealed through the glass, so as to drive a discharge current through the residual gas in the tube (Fig. 94). This simple type of discharge tube has now been adapted to various purposes.

For use in television it must be so arranged that a copious supply of electrons issues from the cathode, these

THE SIMPLEST C.R. TUBE

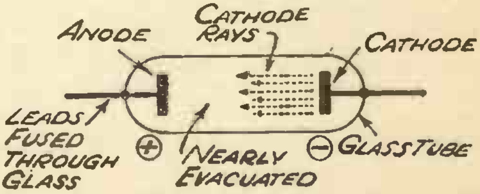


Fig. 94—Simplest form of Cathode-Ray tube, showing anode and cathode, a high electrical potential being applied between these, which causes ionisation by collision in the residual gas

electrons being formed into a stream or beam capable of being focused upon a small spot and of being shifted about and generally controlled at will (Fig. 95). We will not trouble to go into the various stages in the development of the cathode-ray tube, but will proceed at once to describe the tube as it is now used for television reception.

INTRODUCING A FILAMENT

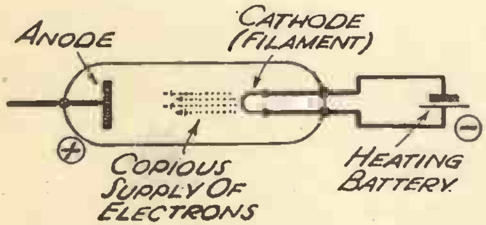


Fig. 95—Simple form of Cathode-Ray tube in which a heated filament is used as cathode, this giving a more copious supply of electrons

General Form for Television Purposes. It contains, of course, two essential electrodes, cathode and anode, across which a potential difference is applied varying between, say, 500 and 2000 volts or higher, according to requirements. Instead of relying upon the residual gas in the tube for providing the supply of electrons (which would give us only a meagre and uncertain electron supply) the electrons are obtained from an electrically-heated cathode, similar to that of an ordinary radio valve. A plentiful supply of electrons is assured in this way and these then move towards the anode under the influence of the electric field existing between the cathode and anode, as mentioned above. By the time the electrons have reached the anode they are moving with a very high velocity and (under proper conditions) a large percentage of them pass through a hole which is pierced in the centre of the anode (Fig. 96).

THE FLUORESCENT SCREEN

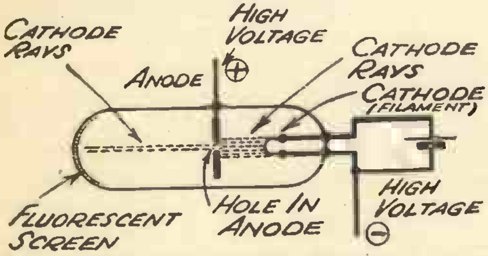


Fig. 96—Simple form of Cathode-Ray tube in which the anode is placed nearer to the cathode and has a hole in it, through which the cathode rays pass, the stream of rays then striking a fluorescent screen at the opposite end of the tube

Nature of Cathode Rays. The result is that at the part of the tube on the opposite side of the anode, that is, away from the cathode, we have a beam or pencil of electrons—or "cathode rays" as they are sometimes called—which continues its career until it eventually strikes the wall of the tube at the far end. The inner surface of the wall here is coated with a material which will glow brightly wherever the cathode beam impinges on it. This effect is known as "fluorescence," and has been referred to in a previous chapter. If the cathode beam shifts so as to strike the fluorescent screen at another spot, the bright glow shifts accordingly, and so we can see at a glance just where the cathode beam is playing upon the fluorescent screen. As a matter of fact, for television purposes we are not directly concerned with the cathode stream at all, and all we need trouble about is the glow which it produces. Perhaps it should be mentioned in passing that the cathode beam itself is invisible.

The "Gun." The cathode and anode, between which a high voltage is applied for accelerating the electrons after they leave the cathode, occupy only a relatively small part of the tube, the major part of the tube comprising the region in which the cathode beam is in free flight after having issued through the hole in the anode. The cathode and anode combination is sometimes referred to as the "gun," for the obvious reason that it serves to shoot out the electron stream, and the voltage applied for this purpose, that is, the 500 to 2000 volts referred to above, is sometimes called the "gun voltage," to distinguish it from voltages which are used in the tube for other purposes, as we shall see presently. Some people refer to the anode itself as the gun, but it is obvious that the term must really include the whole arrangement of anode and cathode.

Tracing the Screen. If everything is symmetrically arranged, the electron stream will strike the centre of the fluorescent screen at the far end of the tube. For television purposes we require to make this spot trace over the screen in successive lines, that is, to "scan" the screen in the fashion which has already been considered in previous chapters. We must, therefore, find some means for making the bright spot on the screen move up and down along vertical lines, and also making it move right and left along horizontal lines. If we have the means to make it

DEFLECTOR PLATES

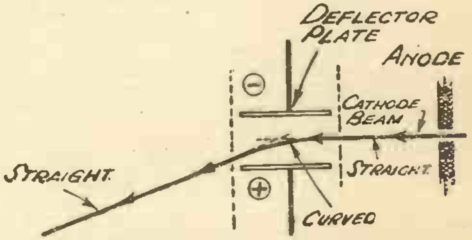


Fig. 97—An illustration of the action of the deflector plates. A suitable electric field is applied across the plates and the cathode beam is continuously bent whilst under the influence of the field. Note that the beam is straight before entering the field and straight after leaving it, but its direction is changed

perform both of these types of motion, it is obvious that we shall be able to make it cover the entire working area of the fluorescent screen in a series of successive lines.

The Deflector Plates. The way we make the cathode beam shift about is as follows: After the beam has emerged through the hole in the anode it is, so to speak, in free flight, but if it passes through a transverse electric field, that is, an electric field operating in a direction at right angles to the direction of motion of the stream, the latter will be deflected, the bending or deflection taking place, of course, parallel to the direction of the force in the electric field. Remember that the beam consists of a vast collection of electrons, that is, negative particles, and these, like any other negative charges, will be repelled from a negatively-charged metal plate and attracted towards a positively-charged plate. Therefore, all we have to do is to arrange a pair of metal plates at a little distance apart, so placed that the cathode beam passes between these plates after coming through the hole in the anode, and apply a suitable potential difference to these plates.

THE PATH OF THE BEAM

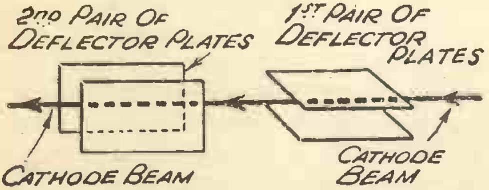


Fig. 98—Showing the two pairs of deflector plates mutually at right angles through which the cathode beam passes after it has emerged through the hole in the anode

Making the Beam Scan the Screen. Let us now go to the opposite end of the tube and look through the glass at the fluorescent screen so that the gun is at the far end and the cathode beam is shooting towards us. If we arrange the pair of plates in vertical planes, the electric field between them will be horizontal and will deflect the cathode beam along a horizontal line, either to

MOVING THE SPOT

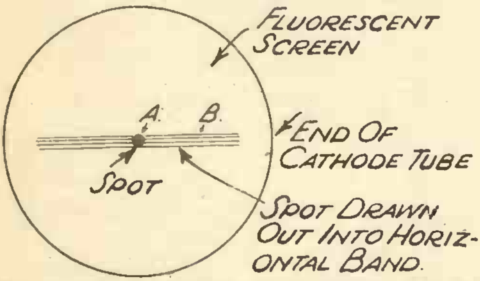


Fig. 99—This is what you see on looking along the axis of the tube at the screen end, the cathode rays shooting towards your eye from the opposite end of the tube. In the centre is the bright spot "A" where the beam normally strikes the screen, whilst "B" shows the effect of applying a horizontal alternating field to the appropriate pair of deflector plates

the right or to the left, according to which way the voltage is applied (Fig. 97). They will, however, be unable to deflect it up or down. In order to obtain the up-and-down deflection we must arrange another pair of plates (Fig. 98), precisely similar to the first but in horizontal planes, so that the electric field between them is vertical in direction, and this field will have the effect of deflecting the cathode beam along vertical lines upwards or downwards according to which way the voltage is applied (Fig. 100).

VERTICAL DEFLECTOR

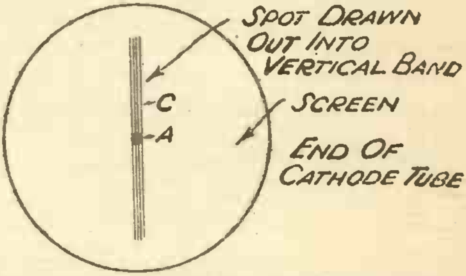


Fig. 100—This diagram illustrates the same type of effect as in the previous one, but in this case the other pair of deflector plates giving the vertical electrical field have an alternating voltage applied to them

Now we have these two sets of deflector plates we can, by applying a suitable voltage across the first set, shift the bright spot on the screen to any required distance to the right, whilst by a suitable voltage on the second set of plates we can shift the spot any required distance upwards (Fig. 100). By a combination of suitable voltages we can, therefore, bring the spot to any desired position on the fluorescent screen.

If the voltage on the pair of plates which creates the horizontal electric field is alternating voltage, the bright spot on the screen will run backwards and forwards along a horizontal line, and if the alternations are sufficiently rapid, we shall be unable to identify the spot, and will see it instead drawn out into a horizontal line or narrow band of light. If we apply a steady voltage to the plates which produce the vertical electric field, we can shift this horizontal line higher up the screen (Fig. 101).

SHIFTING THE BAND

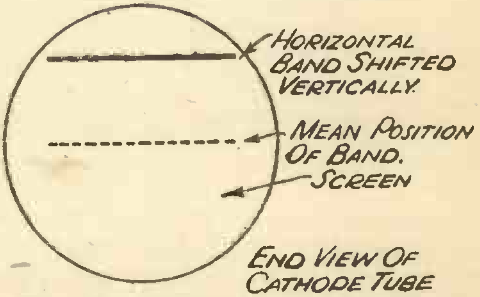


Fig. 101—The horizontal band of light shown in a previous diagram has been shifted vertically by the application of a steady vertical electric field to one pair of deflector plates

If again we apply a slowly alternating vertical field we shall be able to make this horizontal line of light move gradually up and down the screen. Finally, if we make the up-and-down motion sufficiently rapid, we shall be able to render the entire working area of the screen luminous, and we shall be unable to distinguish either the spot itself or the lines.

Synchronising Impulses. Now you have an outline of the manner in which the tube is used for television reception. We have seen in previous chapters how the receiving apparatus is kept in synchronism with the transmitting apparatus so that the spot of light which is flying over the receiving screen and building up the picture keeps in step with the spot of light which is scanning or exploring the picture at the sending end. The methods actually used for synchronising in the case of cathode-ray reception are somewhat different from those used in mechanical systems of television, but we need not go into these at the moment, as they are fully discussed in Chapter 15. It will suffice here to say that synchronising impulses are received, which are used to control the voltages on these two pairs of deflector plates. One set of synchronising impulses keeps the spot flying backwards and forwards along a horizontal line, whilst the other set keeps these lines in gradual procession over the area of the screen (Fig. 102).

COMPLETE SCANNING

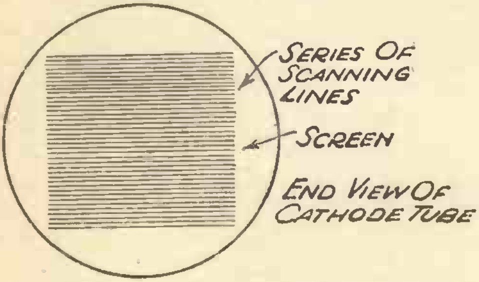


Fig. 102—Showing how the spot of light is made to scan the entire screen in a series of successive lines. In practice the lines are not separated as in the diagram but practically merge together

Brightness of the Spot. The brightness of the spot of light produced on the fluorescent screen by the cathode stream depends upon the amount of electrons in the stream—the copiousness, so to speak—and also upon their velocity. The amount of electrons depends upon the nature and temperature of the cathode, so the temperature forms a control of the strength of the beam, and therefore of the brightness of the picture. The velocity of the electrons depends upon the "gun voltage," and this, therefore, forms another means of controlling the brightness. We shall see later on how the different methods of control are used for "modulating" the beam.

The Colour of the Received Picture. As for the colour of the spot on the screen, this depends upon the nature of the fluorescent material employed. In most cases it gives a bluish or greenish colour, which is rather ghostly to anyone not accustomed to it, but different materials and mixtures have been found which will give a fairly white or sepia illumination under the impact of the cathode rays.

Tube Sensitivity. It will be obvious that the faster the electrons forming the cathode stream are travelling when they shoot through the space between the deflector plates, the greater will be the strength of the electric field between the plates necessary to produce a given deflection of the spot on the screen. To give an idea of actual figures, a well-known cathode-ray tube on the market has a sensitivity of 350 V/mm. deflection on the screen per volt applied to the deflector plates, where V is the gun voltage. Thus, with a gun voltage of 350 volts, the deflection will be 1 mm. per deflecting volt, so that 20 volts would produce a deflection of the spot on the screen of 2 cms.

So far, we have rather assumed that the cathode beam behaves itself just as it ought to do, and gives us a nice, finely marked spot on the screen. Actually, it does nothing of the sort—unless we take special measure to make it do so. In the first place the electrons have various small initial speeds when they "emit" from the cathode, and although the strong attraction of the anode pulls them all more or less into the same direction, the beam is still very diffuse when it reaches the anode. One effect of this is that only a relatively small percentage of the beam gets through the anode. These electrons are still not travelling in precisely the same direction, so that they strike the screen at the other end of the tube over a patch of appreciable area. It is very necessary, therefore, to find means for sharpening-up the spot on the screen. We can do something towards this by adjusting the cathode temperature and the grid voltage, but the effect of these adjustments is small, and we have to rely mainly upon what is known as a "shield."

Focusing to a Sharp Picture. This is a very simple and ingenious arrangement, and consists of a negatively charged

THE FOCUSING SHIELD

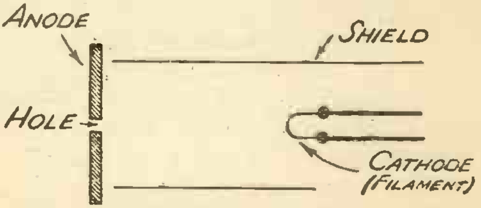


Fig. 103—The focusing shield, which is a metal tube placed around the cathode and continuing nearly up to the anode. This has a negative potential applied to it and repels any wandering electrons back to the axis

metal cylinder surrounding the cathode and continued practically up to the anode (Fig. 103). It is obvious that any electrons which do not make straight for their objective (the hole in the anode), but tend to wander, will find themselves repelled by the negative cylinder and sent back towards the axis of the cylinder, where the forces on them balance out. The result is that this cylinder tends to concentrate the electron beam into a fine stream along the axis. If matters are properly arranged, the axis will pass straight through the hole in the anode, and in this way not only will we get most of the electrons emitted by the cathode into the useful stream, but this stream will also be in the form of a narrow " pencil " of the rays, giving us more chance of a well-defined spot where it hits the screen.

THE COMPLETE C.R. TUBE

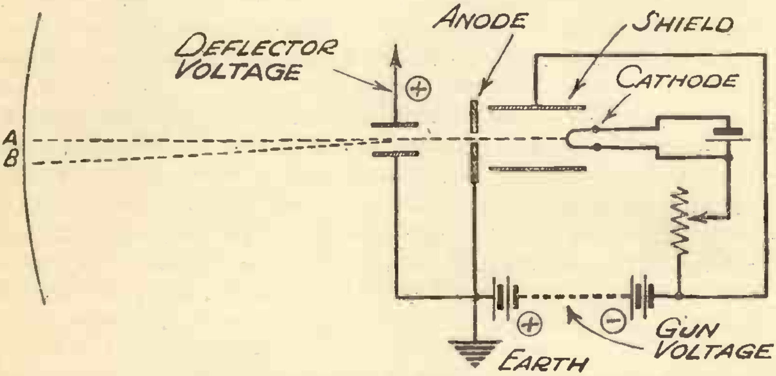


Fig. 104—A simple diagrammatic layout of the entire cathode tube. Note the high voltage battery for maintaining the gun voltage between the cathode and the anode, the latter being earthed. A suitable resistance gives the necessary voltage difference between the cathode and the shield. One of the deflector plates is earthed, the other being " live." On the fluorescent screen the spot " A " shows the normal or mean position of the beam, whilst the spot " B " indicates the position when the beam is deflected

The Negative Shield. This negative shield corresponds, in a general way, to the grid of a wireless valve, and like the grid, will tend to check the emission of electrons from the cathode if made too strongly negative. The negative voltage applied to its depends (like the voltage on the deflector plates) upon the speed of the electron stream, that is, upon the gun voltage. For a gun of, say, 350 volts, it will be 15-20 volts, whilst for a gun of 1000 volts it may have to be increased to as much as 100 volts.

You will have noticed that it is a comparatively simple matter to use the tubular shield in the region between the cathode and the anode, because here the beam remains in the same position always.

After passing through the anode, however, it is deflected by the deflector plates, often through quite a considerable angle, and so it would become a very difficult matter to use any sort of shield tube fitted, so to speak, to the beam at this part of its journey. But this beam still has a tendency to spread, partly because the electrons composing it never were all travelling in exactly the same direction, and partly because of the mutual repulsions of the electrons (all carrying similar electrical charges).

Gas Focusing. Another ingenious dodge is sometimes used here. Let us suppose that, instead of the cathode-ray tube being exhausted to a very low vacuum, there is a small amount of residual gas. (In practice, the air is pumped out "hard" and a small quantity of inert gas, such as argon, is then introduced.) This means that there will be gas molecules wandering about in the path of the electron stream, and when the electrons hit the molecules, they will produce "ionisation by collision," with the result that some of the molecules will be converted into positive ions. These ions will move only slowly (compared to the electrons) and so will stay for an appreciable period in the path of the cathode stream.

The positive ions attract the electrons towards themselves, and so have an effect somewhat similar to that of the shield tube. Instead of repelling the electrons from a surrounding cylinder negatively charged and so forcing them to the axis, as we did with the shield, we make a sort of positive core of gas ions and attract the electrons to the axis. Just how this takes place is not easy to explain, and is, in fact, rather contrary to what you might expect. The fact remains, however, that "gas focusing," as it is called, is very effective in certain conditions.

"Hard" Tubes. For television purposes, if the strength of the beam is being modulated the degree of ionisation is also modulated, with the inevitable result that the focusing is also varied. This is naturally disastrous to the clarity of the picture. Most people prefer to use a "hard" tube (highly evacuated), which does not depend upon the ionisation effect at all, and to employ special forms of gun in order to improve the focus. Hard tubes, by the way, need much higher gun voltages, often as much as 5000 volts.

Magnetic Deflection. For deflecting the cathode beam so as to make it scan the screen, we do not need to use electrostatic deflector plates; we can use instead an arrangement of coils so as to give magnetic control. The coils for this are located outside the tube (Fig. 105). In the same way, we can use a coil "around" the tube (that is, coaxial with it) for the purpose of improving the focusing. The deflector plates located inside the tube are in general use at the present time, but the magnetic system of deflecting has possibilities which may be explored in the future.

In this connection it should be mentioned that the cathode beam is often very sensitive to stray magnetic fields. The inside of the tube is usually coated with graphite or other electrically conducting material, to prevent accumulation of unwanted electric charges on the glass, but this coating only acts as an electrostatic shield, not electro magnetic. Consequently, the beam is at the mercy of any stray magnetic fields, and so precautions must be taken to keep away from leads carrying alternating current, or any similar source of trouble. Anyone who has worked with cathode-ray television reception knows the chaotic effect often produced on the screen by merely switching on an electric light nearby, if proper precautions for screening have not been taken.

USING MAGNETIC DEFLECTORS

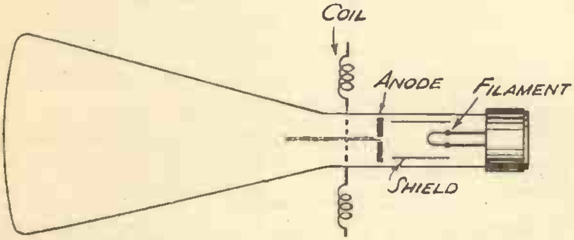


Fig. 105—Instead of deflector plates, coils may be placed outside the tube which, when energised, produce a magnetic field for deflecting the electron stream

Power Supplies. The different electrodes in the tube are connected by leads, fused through the glass to appropriate " pins " in a moulded cap, very much after the style of a radio valve. The tube can thus be connected up for use by inserting the pins into a corresponding socket. A 2-volt battery is often used for heating the filament, this requiring about 2 watts, that is, a current of 1 amp. at this voltage. If the filament is operated from A.C. supply, it is found that the difficulty of sharp focusing is increased.

For the high gun voltage H.T. dry batteries are often used, because the actual current consumed is very small—less than a milliampere. A mains unit may, however, be employed for convenience, but special precautions must be taken to guard against interference.

As regards the voltages applied to the deflector plates, generally one plate from each pair is connected to the anode, which is also usually connected to earth. The cathode is the " live " electrode, so far as the gun is concerned, and the other plate of each pair of deflector plates is supplied with the appropriate voltage. You will remember that for television use the voltages applied to the deflector plates are rapidly varying.

The negative voltage on the shield which may be as much as 100 volts (sometimes much more) is often obtained from batteries, but can be derived from an automatic "grid-bias" arrangement, similar to that used with a wireless valve.

Fatigue and Wearing Out of the Fluorescent Screen. It remains to say something about the life of the tube, for the cathode-ray tube, like the wireless valve and the electric lamp, does not last for ever. The gun current is very small, normally of the order of one-twentieth of a milliamp., but in a gas-focused tube (i.e., a "soft" tube containing a trace of gas) the cathode is bombarded by heavy positive gas ions; the effect of this is gradually to destroy the efficiency of the cathode as an emitter, so that higher and higher values of filament heating current become necessary for proper working. The bombardment of the cathode is increased by increase in the gun voltage, which, however, is necessary sometimes in order to speed up the cathode beam and brighten the spot on the fluorescent screen.

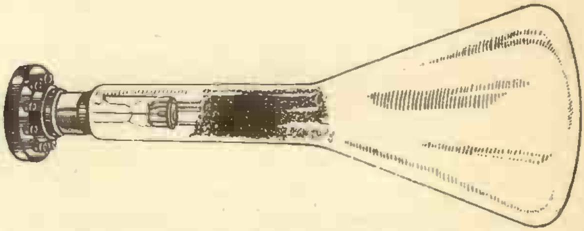

BRIGHT BLACK AND WHITE EFFECT

Fig. 106—A modern cathode-ray tube which gives pictures in practically black and white, and with sufficient illumination for them to be seen clearly in a lighted room

The Life of the Tube. An important factor which limits the useful life of the tube is the "fatigue" or destruction of the fluorescent property of the screen. The greater the intensity or the velocity of the electron stream, the sooner the screen material gets "worn out." The centre spot of the screen is very liable to become a "blind spot," due to the fact that the operator often switches on the tube and allows the full force of the beam to play on this spot for an appreciable time, before setting the deflector plates to work.

The life of a cathode tube under normal conditions, like that of an electric lamp or radio valve, is often given in round figures as 1000 hours.

J. H. T. R.

Chapter 13

THE FLUORESCENT SCREEN

THE NATURE OF FLUORESCENCE—" COLD " LIGHT—ATOMS, ELECTRONS, AND PROTONS—HOW ELECTRONS PRODUCE LIGHT—MATERIALS USED FOR CATHODE-RAY SCREEN.

The fluorescent screen deserves a chapter to itself as the last, and perhaps the most vital, link in the chain of cathode-ray television. Its function is to add the finishing touch to the radiated signals by making them visible to the eye, and the manner in which it performs this duty introduces some of the most interesting theories of modern science.

"Cold" Light. In the first place, fluorescence must not be confused with the intense light given off by bodies at a high temperature. Like the visible rays produced by a glow-worm, it should rather be described as " cold " light. The particular kind of fluorescence which is created inside an evacuated tube by the impact of a stream of electrons, stands rather in a class by itself.

Ordinary fluorescence as seen in the crystal known as fluor spar, and in various chemical solutions and oils, is due to a special form of reflection. In other words, it only shows itself so long as the body producing it is being acted upon by rays of light. The fact that the reflected light is different in colour from the incident or exciting light is due to the peculiar structure of the atoms of the fluorescent material.

Why one substance should be fluorescent, and another not, is a mystery we cannot solve—but there it is. A mirror reflects a ray of light unaltered, whilst a fluorescent body lowers the frequency of the wave in the process of reflection. The altered frequency gives the reflected light its new colour.

Incidentally, the allied effect of phosphorescence is similarly due to a " delayed " reflection, the glow lasting for a considerable time after the exciting light has been withdrawn. For this reason it is important that the viewing-screen in a cathode-ray tube should be as free as possible from any trace of phosphorescence. The scanning movements are far too rapid to tolerate any " lag," such as might cause one picture to overlap the next. Otherwise the whole effect would be blurred.

So far we have only dealt with the kind of fluorescence produced by ordinary light. In the cathode-ray tube, however, we are concerned with the conversion of high-speed electrons into light rays—that is, a change from one form of energy into another of quite a different kind.

Here it is necessary to touch upon the underlying relation between matter and electricity and light.

Atoms, Electrons and Protons. We know that the ultimate make-up of matter is atomic. Also that the atom of matter is not a solid particle, like a small cannon-ball, but consists, as shown in Fig. 107, of a planetary system of fast-moving electrons rotating in orbits around a positive centre or proton.

Similarly the smallest known unit of electricity is the electron. Since this also forms part of the atom of matter, it shows that there must be some intimate connection between the two.

Lastly, we come to light, and here, surprising though it may be, we also find an indivisible unit or " atom " of radiation. It is called the proton, but unlike the electron it is not an invariable quantity. In fact, the shorter the wavelength of the light, the greater is the energy contained in each proton or " packet " of it. But visible (or other) radiation of a given wave-length is always made up of so many protons, each one of which is identical with the others.

NOTHING IS SOLID!

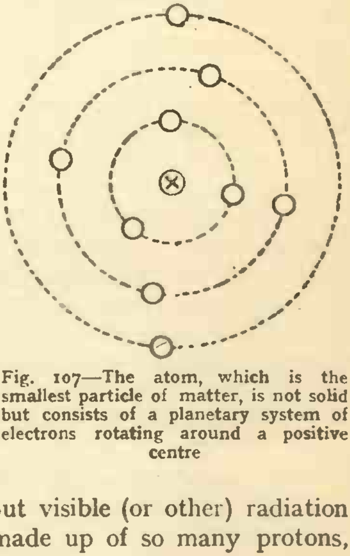


Fig. 107—The atom, which is the smallest particle of matter, is not solid but consists of a planetary system of electrons rotating around a positive centre

We can now return to fluorescence, first as produced by ordinary light, and then as produced inside the cathode-ray tube.

How Electrons Produce Light. When a ray of light falls upon a fluorescent body, one of the protons enters an atom and strikes against one of the satellite electrons shown in Fig. 107. The impact is not sufficient to tear the electron clean away from the atom, but it is sufficient to knock the electron momentarily " off its perch," so that it moves farther away from the centre of the atom. Meanwhile the proton has lost part of its energy in the impact, so that it swings away or is reflected as a wave of lower frequency, and therefore takes on a different colour. It must continue to exist as a proton, but having lost part of its original energy, it can only do so by readjusting its frequency to a lower wave-length, since, as already stated, a long-wave proton possesses less energy than a short-wave one.

Phosphorescence occurs when there is a delay in the return of the electron which has been knocked out of its proper orbit. After a while it reverts to its normal position, and in doing so radiates out the surplus energy it originally acquired from the invader.

The action which occurs inside the cathode-ray tube is very similar, except that it is a case of electron versus electron. One of the free electrons in the cathode-ray stream thrusts itself against a satellite electron in the atom, and jerks it out of its usual orbit. As the latter swings back again to its proper station, it radiates the extra energy derived from the impact as a pulse or proton of fluorescent light.

The intensity of the light so produced depends up to a certain point upon the velocity of the electrons in the cathode-ray stream. As we know, the received picture-signals may be used to control the head-on velocity of the stream, in some cases, or to regulate the speed at which it sweeps over the fluorescent surface (velocity modulation). In both cases the degree of light produced at any given point on the screen represents the corresponding tone value of the same spot on the original picture.

Materials Used for Cathode-Ray Screen. One of the fluorescent materials used for cathode-ray screens is zinc sulphide, which produces a green-coloured light. In the native state it is also usually phosphorescent, and is, on this account, often employed in combination with a suitable radioactive substance, for coating the dials of luminous watches. The phosphorescence has been found to be largely due to the presence of foreign bodies in the sulphide, so that when used for

THE COLOURS THEY PRODUCE

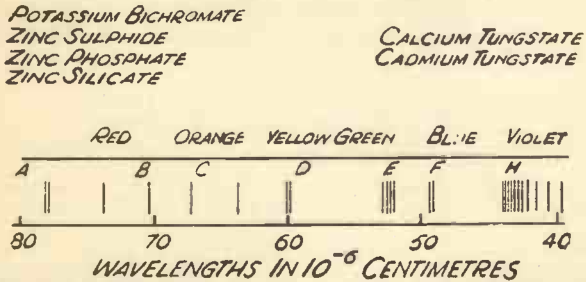


Fig. 108—When certain materials are used for the cathode-ray screen a red fluorescence is produced. With other materials colours of lower wavelength are obtained. By combining various materials a fluorescence giving true black and white pictures is possible

television screens it is first specially purified by chemical treatment.

Potassium bichromate, as indicated in Fig. 108, will give a red fluorescence, and cadmium or calcium tungstate a blue, whilst zinc silicate is greenish. It should, perhaps, be mentioned that all these substances will produce a more intense fluorescence when subjected to the action of X-rays than they do under the impact of electrons ; also under X-ray excitation the colour produced shifts more or less towards the blue end of the spectrum.

By using certain mixtures it is possible to produce a fluorescent light closely approximating to white. This, of course, gives the picture a more natural effect than the greenish, or dark-yellow, tints so often seen in cathode-ray reception. For instance, cadmium tungstate gives a light blue under comparatively low voltages, whilst zinc phosphate produces a reddish colour. A mixture of the two, in the proportion of three to one by weight, will however produce a substantially black and white picture on the screen.

J. C. J.

Chapter 14

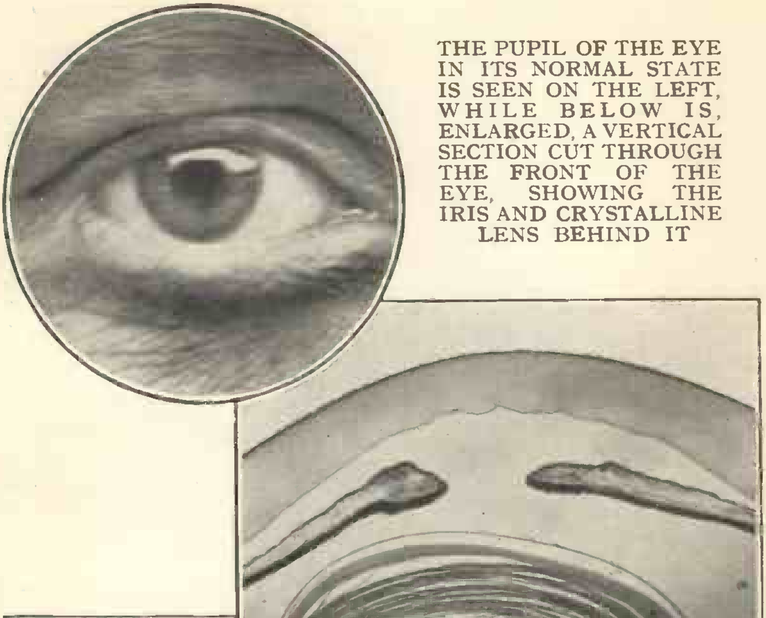
CATHODE-RAY SCANNING

HOW THE PICTURES ARE BUILT UP—INTENSITY MODULATION—VARIATION OF FOCUS WITH INTENSITY MODULATION—"SOFT" AND "HARD" TUBES—SHIELD FOCUSING—THE DOUBLE GUN CATHODE TUBE—DIVISION OF VOLTAGE BETWEEN GUNS—CATHODE-RAY TRANSMITTER SCANNING—VELOCITY MODULATION—"HESITATING" LIGHT-SPOT—IMPROVEMENT OF FOCUS—AUTOMATIC SYNCHRONISATION—AN ALL-ELECTRIC SCHEME—A BRIGHTNESS DIFFICULTY—LOSS OF DETAIL—MIXING INTENSITY AND VELOCITY MODULATIONS—FUTURE OF THE VELOCITY MODULATION SYSTEM.

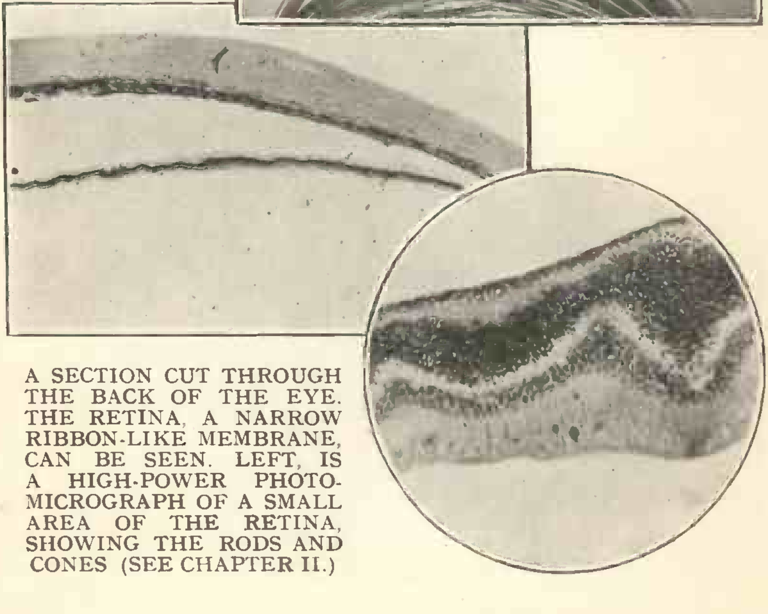
We have seen in the last chapter how the cathode-ray beam is made to shift in such a way that the spot, where it impinges on the screen, is made to traverse the area of the screen, or "scan" it, as it is called, so as to build up the impression of the complete picture in the eye of the observer looking at the screen.

Running the spot in suitable manner over the screen is only one of the essentials to the building up of the picture; the other essential is that the spot shall vary suitably in brightness as it passes from point to point of the transmitted picture. This variation of the light-spot is known as "modulating," a term which is already familiar to us in connection with radio transmission. In sound broadcasting, the carrier waves, or high-frequency ether waves, sent out by the transmitter, are modified (or "modulated") by impressing upon them the characteristics of the speech entering the transmitting microphone; it is these modulating waves (not the high-frequency carrier waves) that are ultimately fed into the loudspeaker and reproduced as sound. In the same way the modulations of the cathode beam in television reception are used to reproduce the light-and-dark characteristics of the transmitted picture.

Intensity Modulation. Now let us consider how this modulation of the cathode beam in the receiving apparatus is brought



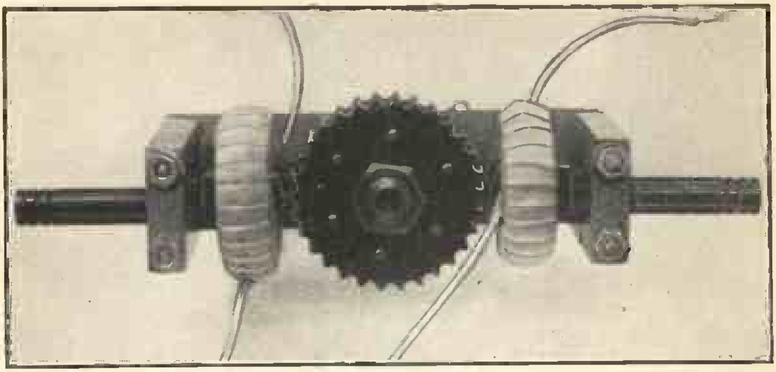
THE PUPIL OF THE EYE IN ITS NORMAL STATE IS SEEN ON THE LEFT, WHILE BELOW IS, ENLARGED, A VERTICAL SECTION CUT THROUGH THE FRONT OF THE EYE, SHOWING THE IRIS AND CRYSTALLINE LENS BEHIND IT



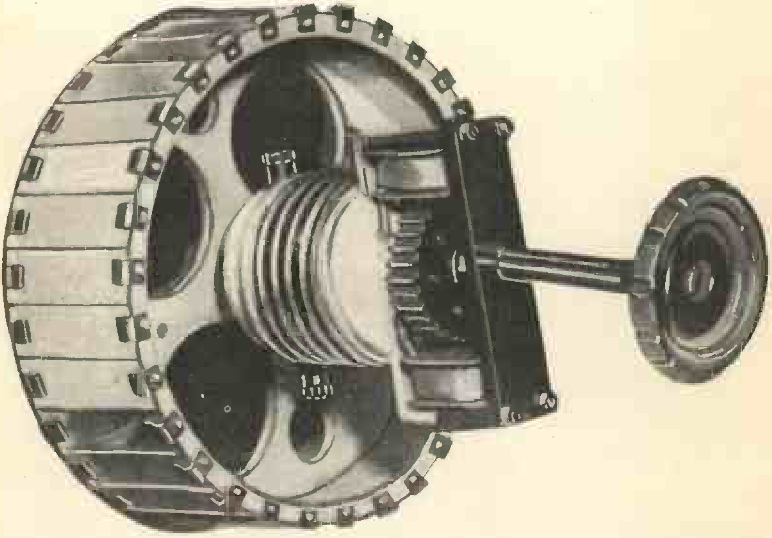
A SECTION CUT THROUGH THE BACK OF THE EYE. THE RETINA, A NARROW RIBBON-LIKE MEMBRANE, CAN BE SEEN. LEFT, IS A HIGH-POWER PHOTOMICROGRAPH OF A SMALL AREA OF THE RETINA, SHOWING THE RODS AND CONES (SEE CHAPTER II.)

Plate 29

EXPERIMENTING WITH THE LATEST DEVELOPMENTS IN TELEVISION RECEPTION IN THE BAIRD LABORATORIES



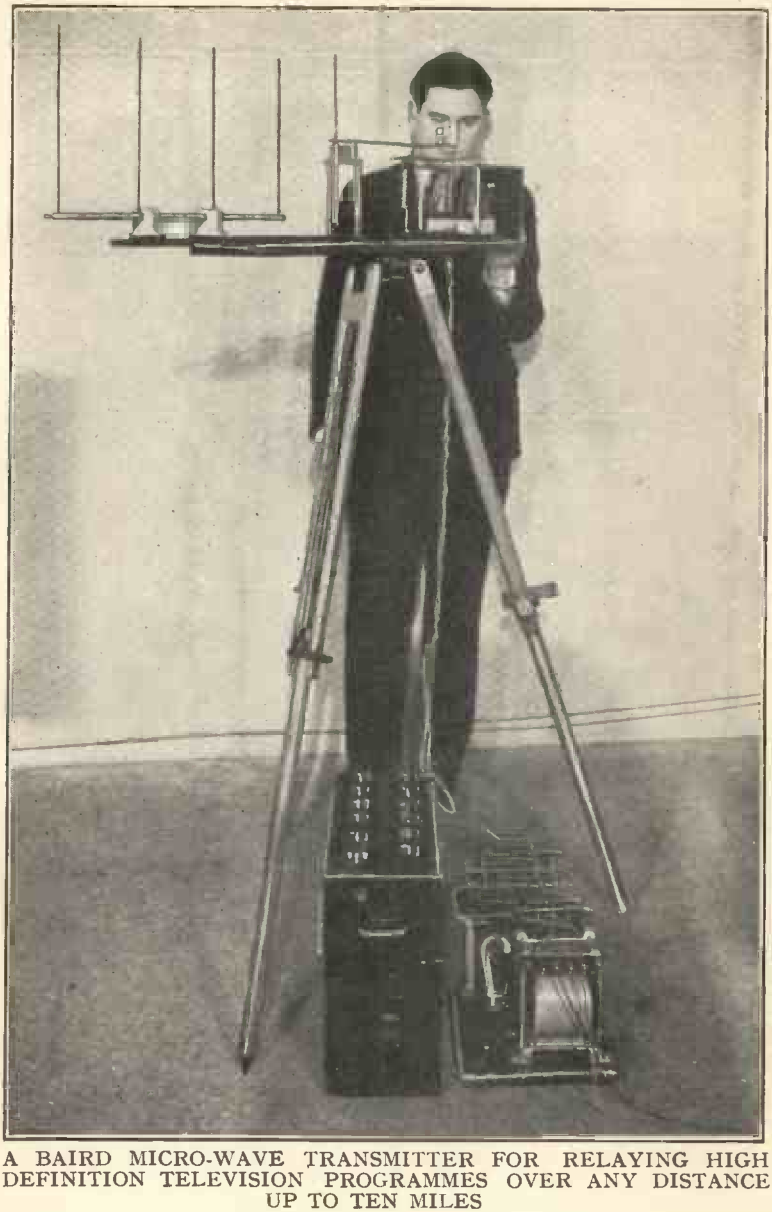
COMPLETE SYNCHRONISER GEAR FOR USE ON A MECHANICAL VIEWER. THE SYNCHRONISING PULSES ARE FED THROUGH THE TWO WINDINGS, WHICH ARE JOINED IN SERIES, AND THE TOOTHED WHEEL IS FIXED TO THE ROTATING SCANNER ON THE TELEVISION VIEWER



A TYPICAL MIRROR DRUM, DESIGNED FOR RECEPTION OF LOW DEFINITION TRANSMISSIONS. NOTE THE INDIVIDUAL MOUNTING OF EACH MIRROR. THE KNOB CONTROL IS FOR SWINGING THE SYNCHRONISER BACKWARDS OR FORWARDS TO OBTAIN CORRECT FRAMING OF THE PICTURE

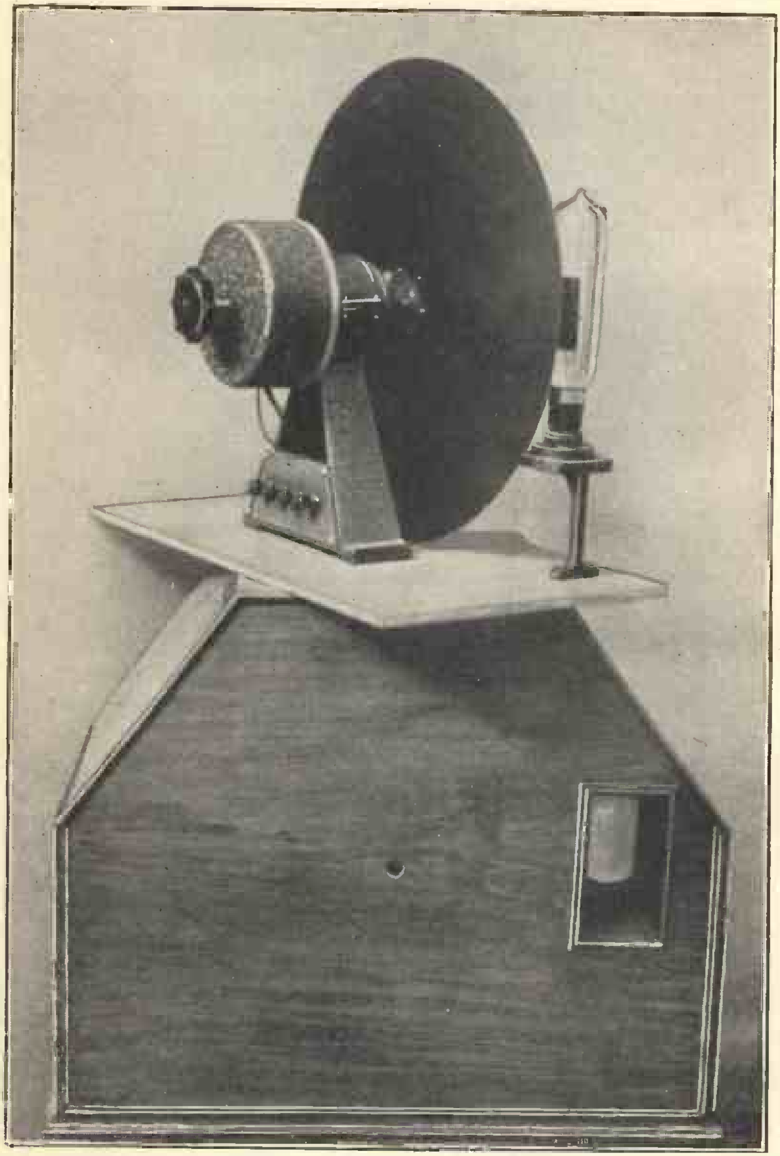
EXPERIMENTAL TELEVISION RECEPTION ON A SMALL CATHODE-RAY TUBE

Plate 32



A BAIRD MICRO-WAVE TRANSMITTER FOR RELAYING HIGH DEFINITION TELEVISION PROGRAMMES OVER ANY DISTANCE UP TO TEN MILES

Plate 33



THE CASE AND INTERIOR OF A 30-LINE TELEVISOR. SYNCHRONISING GEAR IS CONTAINED IN THE ROUND METAL BOX ON THE END OF THE MOTOR BODY about. Broadly, there are two systems of modulation of the cathode beam. The first is called " intensity modulation " and the second " velocity modulation." In intensity modulation the strength or intensity of the cathode beam is controlled or modulated, whilst in velocity modulation the speed with which the beam traverses the screen is the factor which is controlled or modulated. We are now in a position to study these two methods more closely ; we will deal with intensity modulation first.

Variation of Focus With Intensity Modulation. You will remember that the brightness of the spot on the screen will be increased if we increase the amount of electrons in the cathode beam, or their velocity (or both). The voltage of the shield forms a convenient control of the intensity of the light-spot, and under suitable conditions we can obtain the maximum variation of brightness with a variation of the shield voltage of about 20-30 volts. If the tube is a " soft " one, in which use is made of " gas focusing " (as previously described) the sharpness of the focus will vary with the gun current, that is, with the shield voltage. Variations in the focus, or size, of the spot will have the same effect as variations in the intensity, but unfortunately these two effects work in opposition. Otherwise we might be able to turn this accidental circumstance to useful account. When we increase the gun current for the purpose of increasing the brightness of the spot, that is just the time when the spot becomes less sharply focused.

"Soft" and "Hard" Tubes. If we take a given gun voltage, say 600 volts, and then plot on a graph the variations of gun current with shield voltage, we shall see that the gun current increases rapidly as the negative shield voltage is decreased. It will help us very much if we think of the whole arrangement of cathode shield and gun (or anode, as it is best to call it) as corresponding respectively to the cathode, grid, and anode of a triode valve. Just as we can regulate the anode current by varying the grid bias, in the valve, so we can control the gun current by varying the shield voltage. With a typical soft

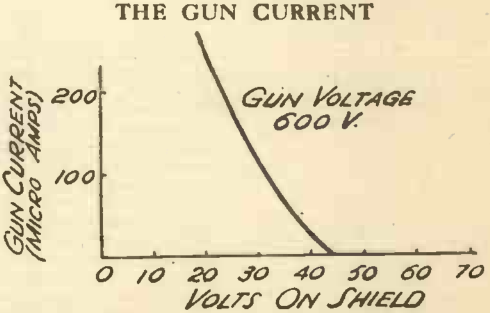


Fig. 109—Graph showing how the gun current varies with the negative voltage on the shield. Taking a gun voltage of 600 volts it will be seen that the gun current becomes zero for a shield voltage of about 45 volts and rises to 200 microamps when the shield voltage is reduced to about 20 volts

tube, the gun current, with 600 volts across the gun, will vary from zero at a shield voltage of 45 volts, up to 200 microamperes at a shield voltage of about 20 volts (Figs. 109 and 110). At the same time, however, the size of the spot will generally increase with the gun current, so that for best focusing we really want to work at low gun currents. A low gun current, however, means a poor brightness of the spot. Thus we go round a vicious circle.

SPOT FOCUS VARIATION

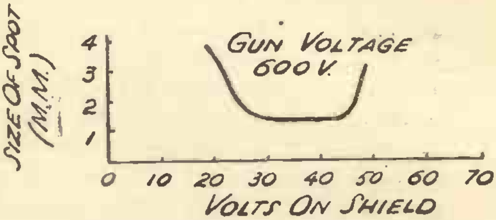
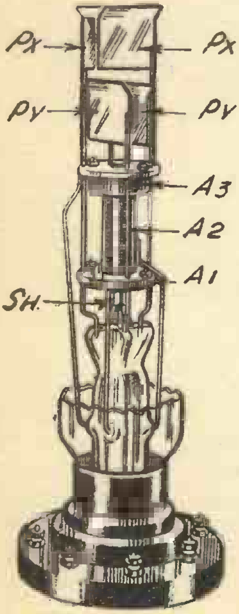


Fig. 110—Graph showing how the focus of the spot varies with intensity modulation. The intensity modulation is brought about by the variation of the shield voltage and, as will be seen, this produces considerable variations in the size of the spot on the screen, that is, in the focusing. This particular figure is for a gun voltage of 600 volts

Shield Focusing. If we turn from using a soft tube to a hard one (Fig. 111), that is, a tube practically free from residual gas, we shall find that the focus of the spot is to a large extent independent of the gun current. This is very good so far as it goes, but now we find ourselves in another difficulty, because we are deprived of the advantage of gas focusing and have to rely upon shield focusing. So that although the focus is fairly constant, it is not good.



THE HARD TUBE

Fig. 111—The electrode structure of a "hard" cathode-ray tube. The cathode is located centrally behind an aperture in the first disc A1 and is surrounded by modulating shield Sh. The third anode A3 has the high gun voltage whilst the second tubular anode A2 is at an intermediate potential, usually about one-quarter that of the third anode. The second anode is the focusing electrode, whilst the modulating shield functions as an intensity control. The tube has in all 10 connections, namely filament (two), shield, first, second and third anodes, and four deflecting plates. One pair of deflector plates are signified by Px and the other by Py. (Courtesy Cossor Ltd.)

The Double Gun Cathode Tube. This difficulty has been the subject of a great deal of research work, and the most promising attempts towards a solution seem to lie in the direction of using a "double gun" (Fig. 113).

This arrangement is precisely similar to that already described, except that a metallic cone is used at the flared end of the tube, forming a kind of second anode. The total anode voltage, or gun voltage, is divided between the conventional gun, which we will now call the first gun, and this conducting cone, which we call the second gun. The voltage allotted to the first gun is usually a few hundred volts, and the cathode beam passes between the deflector plates after leaving the first gun but before entering the second gun.

Division of Voltage Between Guns. The velocity of the electrons is not yet very great (as they have so far only fallen through a potential difference of a few hundred volts), and so they are comparatively easily deflected by the deflector voltages. After deflection, however, they pass on to the second gun, where they are subjected to a voltage of several thousand volts. This very ingenious arrangement has been used by many workers in this field, in various forms, and seems to be a practical solution to the difficulties we have been discussing. The use of the double gun will come up again for discussion presently.

FOR OSCILLOGRAPHS

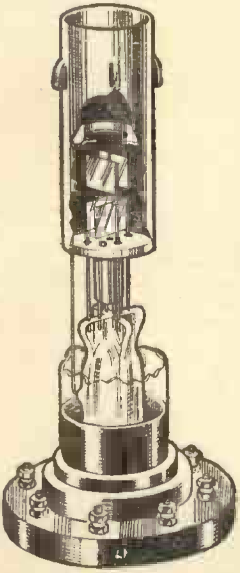


Fig. 112—A view of the electrode arrangement of a cathode-ray tube as used for oscillograph work (Cossor)

Cathode-Ray Transmitter Scanning. Before leaving this part of the subject we may, perhaps, refer briefly to the use of the cathode-ray tube for scanning the "subject" at the transmitter. One simple way of doing this is illustrated in the accompanying figure as applied to the scanning of a film subject (Fig. 114). The cathode beam is made to scan the fluorescent screen in the usual way, and an image of the flying spot is focused, by means of a lens system, upon the film picture to be transmitted. Matters are so adjusted that as the spot traverses the area of the screen, so the image of the spot traverses the area of the film picture. Behind the film is a photo-cell, and the light from the fluorescent spot, on passing through the film, falls upon the cell. Obviously the amount of light falling on the cell will vary from instant to instant as the image of the spot flies over the light and dark parts of the picture. Synchronisation of the light spots at transmitting and receiving ends is carried out as described in another chapter.

A DOUBLE-GUN CATHODE TUBE

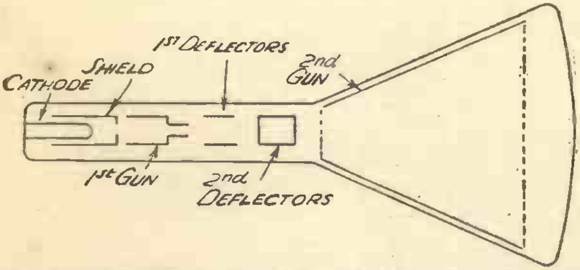


Fig. 113—The electrode system of a double-gun cathode tube. The cathode, shield, and first gun, together with the first and second sets of deflector plates, are seen as before, but in addition there is a conical metal shield in the wide end of the tube, which has a voltage of several thousand volts above the other electrodes applied to it and forms a second accelerator or gun

Velocity Modulation. Now we come to the other method of modulation to which we referred at the beginning of this chapter, namely, velocity modulation. To understand the underlying principle of this, let us take a simple illustration. Take in your hand a glowing match and wave it rapidly to and fro (not in a circle) through a distance of, say, six inches (Fig. 115). You will notice that at the ends of its excursions it will appear much brighter than at the intermediate positions. This is due to the fact that the match is moving most rapidly at the middle part of its journey, whereas it is slowing up as it comes to the end, and at the end of each journey it is momentarily at rest. Consequently there is, so to speak, more time for the eye to see it at the ends of the journeys than at the middle. The same sort of thing will be seen if you stretch a string between two supports and then "twang" it in the middle; it will vibrate to and fro rapidly, and you will see it clearly at the two extreme positions, but only hazily in the intermediate part. This is because it is moving rapidly at the middle and is stationary at the ends (Fig. 116).

"Hesitating" Light-Spot. We have seen then that we can make a spot of light, of constant brightness, appear to vary in brightness according to the speed or velocity with which we move it about. Let us apply this to the television receiving screen.

Suppose the spot of light which is moving over the screen in the cathode-ray tube "hesitates" for a little on a particular point, that point will appear brighter than the rest of the screen. Now suppose the scanning spot at the transmitting end can be made to hesitate or move more slowly at the bright parts of the picture, and more rapidly over the dark parts, and that the scanning spot at the receiving end can be made to follow suit, clearly we shall have a simple means of building up the picture, even though the cathode beam be of constant intensity. You see then that we can move the beam over the screen at constant velocity, whilst modulating its intensity from point to point (" intensity modulation ") or we can move a constant-intensity beam over the screen whilst modulating its velocity from point to point ("velocity modulation"). Note that velocity modulation refers to the velocity of traverse of the light-spot over the screen, not the velocity of the electrons in the cathode stream, as some people imagine.

SCANNING A FILM

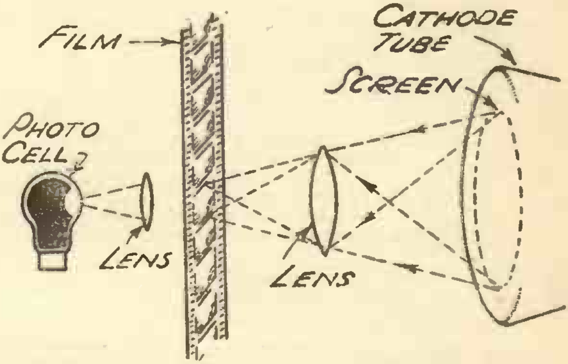


Fig. 114—Illustrating the principle of cathode-ray scanning of a film at the transmitting end. The working area of the cathode screen is focused by means of a lens system upon the picture area of the film. The fluorescent spot scans the screen and consequently the image of the spot scans the film ; the light passing through the film (which is fluctuating in brightness according to the light and dark parts) then falls upon the photo-cell

Improvement of Focus. You will remember that one of the fundamental difficulties of intensity modulation was the variation of the focusing with variations of the gun current. With velocity modulation, however, we have a system which (apart from any other drawback it may have, which we will look into presently) has at once the great advantage that the gun current is constant and therefore the focusing trouble is abolished at one fell swoop!

It will be convenient to consider again the transmitting end of the system. Here we have precisely the same arrangement as that already described, the beam scanning over the fluorescent screen, the image of the spot being focused on the subject (film) and scanning it in similar manner, the transmitted light (fluctuating as it passes over bright and dark parts) falling on a photo-cell behind the film. The additional feature, however, is that part of the output from the photo-cell amplifier is now turned back and used to control the scanning speed of the beam—a kind of "reaction" or "feed back" effect. Thus when the scanning spot is passing a bright part on the film the increased output from the photo-cell has the effect of slowing down the spot, whilst the reduced output from the photo-cell when a dark part is encountered has the effect of speeding up the rate of traverse of the spot.

ILLUSTRATING VELOCITY MODULATION

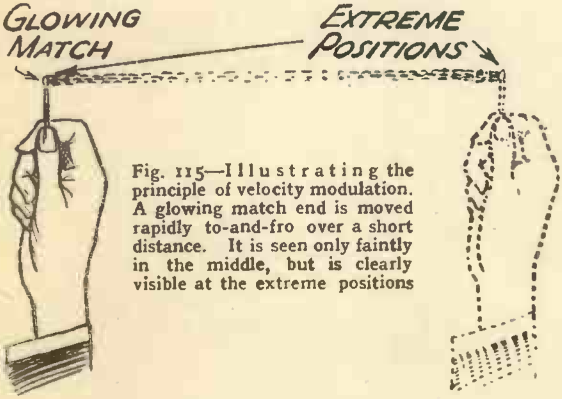


Fig. 115—Illustrating the principle of velocity modulation. A glowing match end is moved rapidly to-and-fro over a short distance. It is seen only faintly in the middle, but is clearly visible at the extreme positions

Automatic Synchronisation. If you think about it for a moment you will see that since a bright spot on the film means a hesitating of the scanning beam, the scanning spot will itself build up an image of the film picture on the fluorescent screen of the transmitting cathode-ray tube. For this reason it is sometimes said that the tube, in this arrangement, is "self-monitoring." This is very interesting, but a much more important point which emerges here is that, by a very simple process, we can dispense with ordinary synchronising arrangements between transmitter and receiver! The deflector plates of the transmitter are subject to certain fluctuating voltages (characteristic of the film picture); if we can transmit these fluctuations to the deflector plates of the receiver, we have everything needed.

YOU SEE IT CLEARLY AT THE ENDS

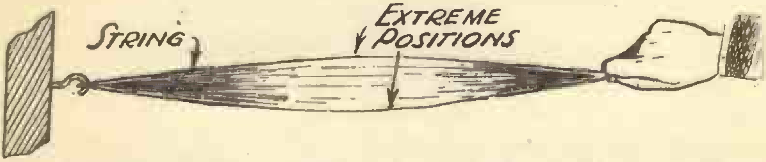


Fig. 116—The stretched string is vibrating and is seen clearly at the ends of its excursions owing to the fact that it comes momentarily to rest there: it is moving rapidly in between

An All-Electric Scheme. The only drawback to this is that it requires two separate transmission channels, and as one of the great problems of television generally is the provision of channels, this is a serious objection. We must, for practical purposes, confine ourselves to one channel, and therefore we have to sacrifice part of the "complete absence of synchronisation" feature. What is done is to make the transmission "self-synchronising" as regards the line-scanning, using a synchronising impulse (on the same transmission channel) for taking care of the picture-scanning. The synchronising signal used for the pictures is of such a character that it needs no adjustment at the receiving end. In other words, although there is in reality a synchronising signal, it is automatic, so that for practical purposes the system is self-synchronising. Furthermore, everything is electrical (that is, there is nothing "mechanical") at both transmitting and receiving ends.

A Brightness Difficulty. A possible difficulty that will occur to you is this. Suppose we strike a run of a few very bright pictures on the film (assuming now that the film is passing forward at the usual rate), the scanning spot will move more slowly and the pictures will not be completed in the time allotted per picture. To get over this, the mean scanning speed is made constant by a very simple circuit arrangement.

We have already seen that at the receiving end all we have to do is to feed the received impulses to the cathode tube in such a way that the two pairs of deflector plates change their respective voltages in a manner corresponding to those of the deflectors of the transmitter. The absolute brightness of the received picture (or the average or mean brightness) may not be at all similar to that on the transmitting tube; it depends, obviously, upon the gun voltage, cathode temperature, and other conditions in the receiving tube itself.

Loss of Detail. So far we have seen the advantages of the velocity modulation system, which are undoubtedly very remarkable. It has, however, the disadvantage that, since it depends for the dark parts of the picture upon extreme rapidity of movement of the cathode beam, there is a tendency for the "detail" in the dark parts to be lost, albeit the detail in the bright parts may be very good. To get over this drawback, it has been found useful to employ a kind of mixture of the two types of modulation which we have discussed, that is, velocity and intensity modulation.

Mixing Intensity and Velocity Modulations. To understand this, let us suppose that the pure velocity modulation system is used, but the difference in the velocity between dark and bright parts of the picture is not very pronounced. On the receiving screen what we shall get will be a reproduction of the original, but with insufficient contrast between bright and dark. If now we superimpose on this, as it were, an intensity modulation, we shall be able to improve the contrast without speeding up the velocity modulation system. Where the scanning spot is moving slowly, making a bright part on the picture, the shield voltage will be automatically reduced, thereby increasing the gun current and so increasing the intensity of the beam. You will recollect that the great disadvantage of the intensity modulation system was the variation of focus with modulation, and you may therefore conclude that this difficulty will be reimported into the scheme if we use intensity modulation again.

It is found in practice, however, that by splitting up the modulation into two parts, giving one part to velocity modulation and the other to intensity modulation, we can get the best out of each system and, to a large extent, avoid the peculiar drawbacks of each. In other words, since the degree of modulation called for on each system is relatively small, we get both systems working in favourable conditions.

Future of the Velocity Modulation System. It is perhaps early days to say what the possibilities of the velocity modulation system may be. It has the very great (and very extraordinary) advantage that for practical purposes there is a complete absence of synchronisation, whilst a minor but nevertheless important point is that it is adapted for use with ordinary cathode tubes and does not require any of special or complicated design. At first sight you would think that velocity modulation would be much more complicated than intensity modulation, but it turns out to be extremely simple. Many experts believe that the future of television lies along these lines, but that is yet on the knees of the gods.

J. H. T. R.

CHARACTERISTICS OF TYPICAL HARD CATHODE-RAY TUBE.

(Cossor.)

Maximum diameter	12¼ in.
Length	26 in.
Cap	10 pin.
Socket	10 pin, special ring type.
Filament current	1.25 A.
Filament voltage	0.4 V.
Third anode voltage	4,000 V. max.
Second anode voltage (focusing control)	¼ of third anode voltage.
First anode voltage	From 0 to second anode voltage.
Shield voltage (negative)	Equal to first anode voltage.
Working grid base	¼ of first anode voltage.
Electric sensitivity at third anode voltage V.	$\frac{750}{V}$ mms. per volt.

Chapter 15

BUILDING UP TIME BASES

THE TWO METHODS OF DEFLECTION—MOVEMENT OF THE BEAM—CHARGING THE CONDENSER—USE OF GAS-FILLED RELAY — SYNCHRONISING — THE HIGH-VOLTAGE CIRCUIT—CIRCUITS USING HARD VALVES—THE MULTI-VIBRATOR.

A large number of circuits have been developed for producing the scanning lines on the screen of the cathode-ray tube, some of which appear very complex at first glance. If, however, the basic principles of the scanning circuit are understood the reader will have no difficulty in following the modifications which have been made or in seeing the reason for them.

The problem of scanning is quite definite and can be stated thus: The beam must be moved across the screen at a definite and uniform rate, i.e., it must cover equal distances in equal intervals of time. At the end of its travel the beam must return to the point from which it started with the minimum of delay.

While the beam is swinging to and fro across the screen in one direction a second similar movement is given to it, which displaces it by small amounts in the direction at right angles to its movement. Thus each swing of the beam occurs at a slightly different point on the screen, and the combined movement gives it the appearance of drawing a series of lines across the face of the tube.

The two movements are identical in action except that one is at right angles to the other and at a different rate. The two rates of movement for a high definition 240-line screen are shown in Fig. 117, from which it is seen that the horizontal travel of the beam must be accomplished in 1/6000th sec. and the vertical "ratcheting" movement is moving the beam completely across the screen in 1/25th sec. At the end of the travel the beam has scanned the screen once and returns to its initial position ready to make the journey again. Since the two movements are the same it is only necessary for us to consider the fundamental problem of how to move the beam uniformly across the screen and return it after a given length has been travelled.

We have seen that there are two ways by which the beam can be deflected electromagnetically, by means of coils, and electrostatically by means of a potential applied to the deflector plates. Here again, since the current through a coil is proportional to the potential across it (neglecting for the moment any complications due to inductance), we can leave the first and consider only the deflection of the beam by a potential on the plates of the tube.

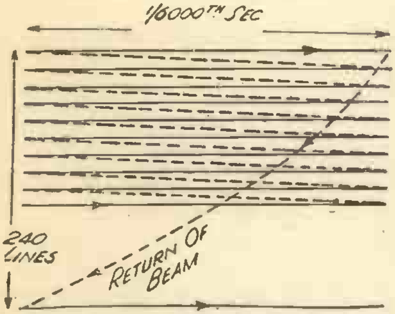

PATH OF THE BEAM

Fig. 117—The path of the beam on the screen of the tube when drawing a high definition television screen. The speed of travel is shown in each direction

Movement of the Beam. The movement of the beam in a high vacuum tube is proportional to the potential applied to the plates, and it will follow variations in the potential lasting for 1/1,000,000th sec. with ease! We can, therefore, turn our requirements in movement into terms of potential on the plates, and state that in order to give a uniform travel to the beam, a uniformly increasing potential must be applied to the plates.

Suppose, for example, that the beam moved 0.5 mm. for each volt applied to the plates. If a potential were applied increasing uniformly from 0 to 100 volts in 1 sec., the rate of increase would be 1 volt in 1/100th sec. and the beam would travel across the screen at the rate of 0.5 mm. per 1/100th sec., completing its journey of 50 mm. in 1 sec. Now, if at the end of that time the potential were switched off, the beam would immediately fly back to its original position until the switch closed again (Fig. 118).

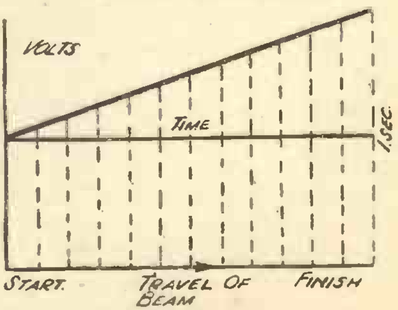

UNIFORM MOVEMENT

Fig. 118—A uniformly increasing voltage applied to the deflector plates produces a uniform movement of the beam

The scanning problem therefore reduces to the provision of a potential which can be increased uniformly for a given time, and then abruptly decreased to zero. It is theoretically possible to do this by means of a potentiometer with a rotating contact arm arranged to tap off uniformly increasing potentials from the wire, and then, at a given moment, open-circuiting the supply.

This is not practically possible though, on account of the high speed of movement required. No mechanical contact could withstand a repeated travel of 1/25th second duration, much less one of 1/6000th sec. A satisfactory mechanical "contact maker" has been made, although the only mechanical part about it was a small motor which drove a disc with a graduated aperture on its circumference.

EFFECT OF RESISTANCE

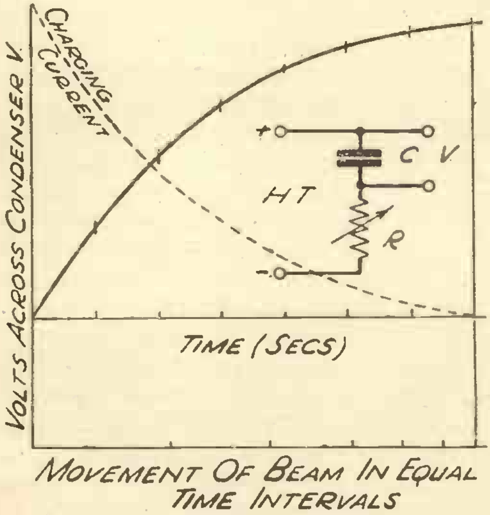


Fig. 119—The curve of condenser voltage when charging through a resistance R. Since the increase is non-uniform the beam will move irregularly as shown

Through this aperture a light shone on a photo-cell, the current in which increased uniformly with the increased light falling on it from the aperture. By means of the usual amplifier this current variation was translated into potential increase at the output stage, which was then connected to the deflector plates.

This system cannot be said to be truly mechanical, since the essential part was the photo-cell, but it is interesting as showing a method of adapting a well-known electrical effect.

By far the most simple and satisfactory way of producing a uniformly increasing potential is that of charging a condenser.

The deflector plates of the tube being virtually an "open-circuit" can be connected across the terminals of the condenser and will experience whatever change in voltage takes place across the terminals.

Charging the Condenser. If a condenser is connected across a H.T. battery, through a resistance, we know that it will become charged, that is, current will flow into the condenser until its potential is equal to that of the H.T. applied. The charging current at the moment when the switch is closed is very high, but falls in value until when the condenser is fully charged it is zero. The variation in charging current is not uniform, but follows what is called an "exponential law." This term is best understood by referring to Fig. 119, which is a curve of current flowing into the condenser for a given time.

USING A PENTODE

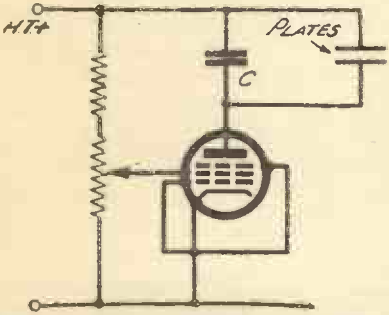


Fig. 120—The substitution of a pentode for the resistance of Fig. 119 gives a uniform charging rate to the condenser

The potential across the condenser will rise according to a similar law, and its curve, plotted to the same time scale, will be the thick line. The formula from which the value of voltage is found at any instant, is too complex to be dealt with here, but one important point may be noted: the time taken for the condenser potential to reach a given point on the curve is dependent on the product CR, C being the capacity of the condenser in farads and R the charging resistance in ohms.

The effect of these constants will be seen later in Fig. 125. Considering the curve shown it is obvious that the potential applied to the deflector plates will not give a uniform movement to the beam; in fact, the movement will be that of the line shown underneath the curve, where the divisions represent equal intervals of time. A modification must be made to the circuit to produce a linear rate of increase of the condenser potential, and this is done by replacing the resistance with a valve of the pentode type. The characteristic of such a valve, as is well known, gives a constant anode current over a wide range of anode voltage variation.

The circuit is then connected as in Fig. 120. When the condenser is switched on, the potential across it is zero and the charging current immediately flows. As the potential rises, the anode voltage of the pentode falls, the sum of the two potentials always equalling the applied H.T. voltage. Because of the pentode characteristic, however, the falling anode voltage produces negligible change in the charging current through the valve, and the condenser continues to charge at a constant rate.

The rise in condenser potential instead of following the curve of Fig. 119 is straightened out and becomes approximately a uniform increase with respect to time. If the pentode characteristic were a horizontal line the charging curve would be quite straight, but in practice it is sufficiently linear for us to use this circuit as a means of producing a uniform movement in the beam.

The next step is the provision of some arrangement for short-circuiting and discharging the condenser at a given potential. Here again a mechanical device, such as a rotating contact, is possible but not desirable. If we can use electrical means it will be quieter and less liable to develop trouble. The use of a neon lamp connected across the condenser will give the required action, since the impedance of the lamp when the glow starts is very low. The neon lamp has the further property of maintaining its discharge although the voltage across it may be reduced below that required to start the discharge: a kind of " glow lag." Accordingly, the lamp is connected across the condenser as shown in Fig. 121, and the action is then as follows: The condenser charges at a uniform rate according to the curve until its potential is about 170 v. This is sufficient to start the discharge in the lamp, i.e. to " strike " it. As soon as the lamp strikes the condenser discharges through its low impedance path and the potential rapidly falls. The glow will persist until the potential across the lamp has fallen to about 130, when it will go out and the lamp impedance rises again. The condenser then re-charges to the original high value, discharges again, and so on, at a rate depending on the value of charging impedance and its own capacity.

DISCHARGING THE CONDENSER

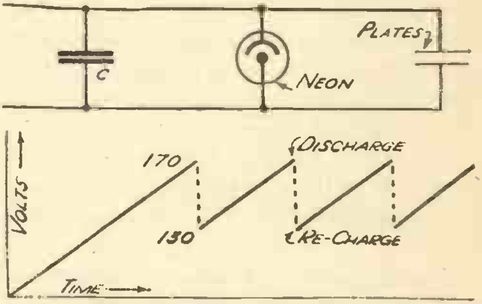


Fig. 121—Discharging the condenser by means of a neon lamp connected across its terminals. The curve below shows the variation of voltage as the condenser charges and discharges

Use of Gas-Filled Relay. The curve below the diagram shows the voltage changes taking place across the condenser, which are in the nature of a saw-tooth wave, in fact, this name is given to types of oscillation produced by the discharge of a condenser in the circuits similar to the one shown. The total variation of voltage applied to the deflecting plates is only 170—130, 40 v., and this is insufficient to give a full traverse to the beam. The output from the neon lamp can therefore be amplified by one or more valve stages, until the voltage swing in the output stage is sufficient. The actual value required is dependent on the sensitivity of the tube used, but if a 7-in. screen is to be covered, at least 300 volts will be needed. For this reason, and for other disadvantages which will be seen later, the neon lamp discharge device is not used to a great extent. A great improvement can be made by replacing the neon lamp with a gas-filled relay, such as the so-called "thyratron."* The gas-filled relay is really a "soft" three-electrode valve, in which a globule of mercury is introduced, thus filling the bulb with mercury vapour. When the cathode is heated the electrons produced collide with the vapour particles producing positive ions.

These ions migrate to the cathode, being positively charged, and set up a conducting path in the cathode-anode space. The presence of the ions enables a much heavier current to be handled by the valve than if it relied on plain electronic emission. An important effect of the positive ions is to reduce the impedance of the valve to a very low value, and the current flowing in the anode circuit is therefore only limited by the external resistance in the circuit.

The anode voltage required to produce ionisation is only 15-20 volts, and hence the flow of current in the valve will take place as long as the anode potential exceeds this value. The use of the grid is to control the anode potential at which ionisation commences. If the grid is biassed negatively the potential applied to the anode must be raised to a value sufficient to neutralise the negative field of the grid before ionisation will take place. More simply, the grid acts as a trigger which controls the point of discharge in the valve.

STRIKING POTENTIAL AND BIAS

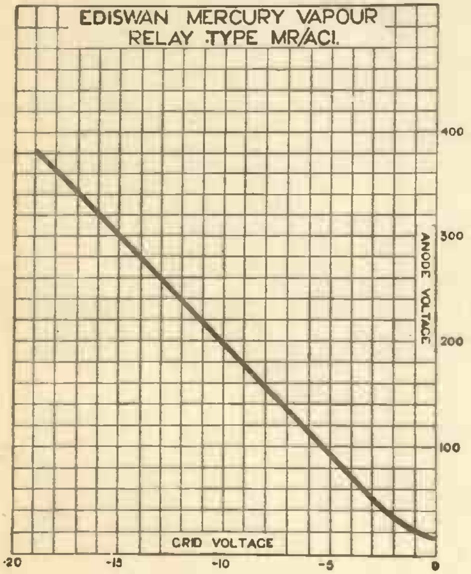


Fig. 122—"Control" characteristic of Ediswan relay, giving the relation between striking potential and grid bias

Once the discharge has started, however, the grid no longer has any control, since the negative bias now serves

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* The word "Thyratron" is the trade name used by the British Thomson-Houston Co., and is strictly speaking only applicable to relays of their manufacture.

to attract positive ions and not to affect the electron emission. Before the discharge can be stopped the anode potential must be reduced below the ionisation value of 15 v. The "control ratio" of the relay is the amount by which the anode potential must be raised to start ionisation for each volt applied to the grid.

The curve of Fig. 122 is that of the Ediswan MR/AC.1 relay and shows the relation between the striking potential and the grid bias. The control ratio is thus 20-1. In practice, after the valve has been running for a little time the pressure of the mercury vapour increases and this has the effect of altering the value of anode potential at which the discharge commences.

It is usually necessary to run the valves for a few minutes to allow them to become stable, before any adjustments are made to the circuit. If the mercury vapour is replaced with an inert gas, such as helium or argon, there is less tendency to variation in the ionising potential, and more stable operation is obtained. The gas-filled type of relay is thus more suitable for television circuits. The full circuit using a gas-filled relay for discharging the condenser is shown in Fig. 123.

INTRODUCING A RELAY

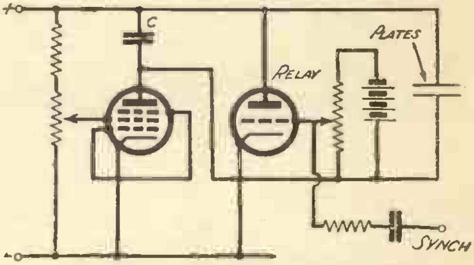


Fig. 123—The neon lamp of Fig. 121 has been replaced by a relay. Connection is made to the grid of the relay for applying a synchronising impulse

The anode and cathode are connected across the condenser, and the grid of the relay is biased from a battery and potentiometer. Suppose the bias applied is 10 volts. With a control ratio of 20-1 this means that the anode potential will have to reach 200 volts before the discharge will commence. The condenser will therefore charge to 200 volts, but once the discharge has commenced it will continue until the potential has fallen below 15 volts. Herein lies the advantage of the relay as a discharger—the range of voltage is greatly increased and the travel of the beam is correspondingly greater.

Synchronising. The length of travel is also controllable by the bias applied to the grid, which, of course, is not possible in the case of the neon lamp. In the diagram of Fig. 123 a terminal will be noted marked "Synch.," short for "synchronising." This is connected through a high resistance and an isolating condenser to the grid of the relay, and has a very important part in television scanning since it enables the speed of discharge of the condenser to be kept in step with the received picture impulses.

THE SYNCHRONISING IMPULSE

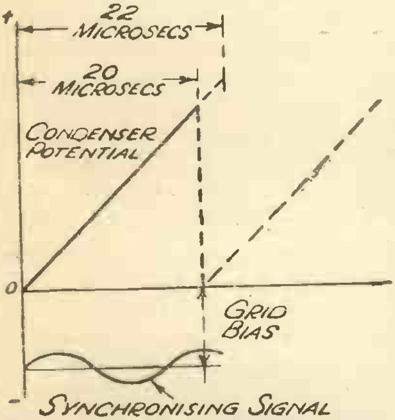


Fig. 124—How the synchronising impulse applied to the grid discharges the condenser at regular intervals

The action of the synchronising circuit is seen in the diagram of Fig. 124. Suppose a sine wave of low voltage is applied between the "Synch." terminal and the cathode of the relay. The grid will then have a fluctuating potential applied to it which will add to and subtract from the bias at regular intervals. This is shown by the curve below the zero line in the diagram.

Now suppose that the condenser circuit is adjusted to charge to 200 v. in 22 milliseconds corresponding to a speed of 45 discharges per second. At the end of 20 milliseconds the condenser will not have reached 200 volts, but the bias applied to the grid of the relay will be reduced by the peak of the applied sine wave which occurs every 20 milliseconds.

The striking voltage of the relay will thus be reduced by a few volts, and the condenser will discharge. In other words, the condenser is being forced to discharge at the end of every 20 ms. whether it has reached 200 volts or not. This means, that if the scanning speed tends to lag it is automatically pulled into step with the incoming signal. The synchronising impulse is most effective on a slow-running relay; if the condenser timing is faster than the synchronising impulse it will have discharged and be commencing the next charge before the grid bias is altered by the incoming wave. Fig. 123 can therefore be taken to represent the fundamental circuit on which the scanning arrangement is based.

To scan the screen in two planes, two condenser-relay combinations will be required, one to produce the line travel at 6000 sweeps per second, and the other to move the beam completely across the screen 25 times per second. Since the speed of scan is proportional to the product C.R., there is, obviously, an infinite number of values of capacity and resistance which can be chosen to give a certain speed.

The practical limitation to the values is set by the behaviour of the relay itself. If the condenser is too big, an excessive current will flow through the relay on discharge and heavy sparking will take place at the cathode. If too small, there is a possibility of unwanted oscillations taking place in the discharge circuit. A heavy discharge current can be prevented by the insertion of a resistance in the anode circuit of the relay, but this has the effect of slowing down the discharge of the condenser, and the return stroke of the beam then interferes with the scanning.

Normally, the return stroke only occupies a few millionths of a second—the time taken for the discharge to start in the relay—but if the resistance of the discharge path is appreciable the time taken for the beam to return to its original position becomes comparable with the speed of travel, and the scanning lines will appear as a zig-zag.

High Voltage Circuit. A successful attempt has been made to simplify the circuit of Fig. 123 by reverting to the resistance charging arrangement, and raising the applied potential. The curve of charging potential is, as we have seen, logarithmic, but if a magnified

A CURVE PLOTTED FROM ACTUAL VALUES

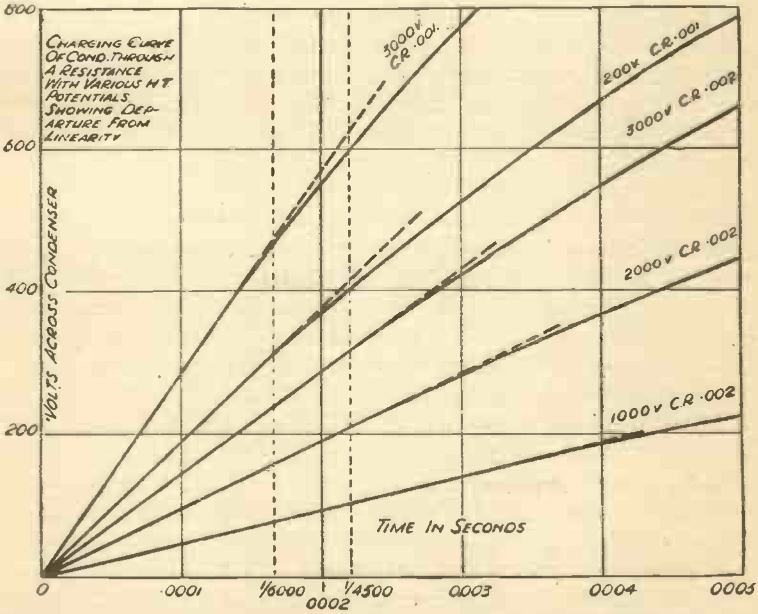


Fig. 125—The charging curve of a condenser is straight for the initial part. The dotted line shows where the curve commences to bend over

portion is taken at the commencement it will be found to be practically linear.

This linear portion can be used to produce the beam deflecting potential provided that the relay strikes before it becomes too curved. To ensure sufficient potential to give a full travel to the beam the H.T. applied to the scanning circuit must be high in order that the linear part of the curve reaches 200-300 volts.

This requires 1500-2000 volts. The curve of Fig. 125 is plotted from actual values of condenser and resistance, and shows the point at which the curve departs from the straight to such an extent that the scanning would not be uniform. The dotted line shows the time interval required for a 1/6000th sec. scan, and provided that the condenser potential reaches a value between 2-300 volts at this point a satisfactory scanning circuit results.

The replacement of the pentode by the resistance is more economical and leads to greater constancy, but the drawback of the high voltage required limits the application of the circuit and necessitates specially picked components. For experimental work, however, it is simple to construct and reliable in operation.

Circuits Using Hard Valves. The gas-filled relay in itself is not free from certain disadvantages, which have led investigators to develop circuits avoiding its use. Apart from the variation introduced by temperature, mentioned earlier in this chapter, the operation of the relay makes the speed of travel and the length of travel, to some extent, dependent on one another. This means that an alteration in length of scan will affect the speed of charge and discharge, and compensation must be made each time the length is adjusted.

A circuit in which hard valves are used is inherently more stable and constant in operation than one using a gas discharge device. Modern thermionic valves are made to such high standards and are so reliable that their performance can be estimated with great accuracy. The problem in designing hard valve circuits is to imitate the rapid discharge which is so successfully accomplished by the thyratron, and this is not easy, since the characteristic of the triode valve is one of gradual change of current.

The control grid has no trigger action, as in the case of the relay, but only serves to control the value of anode current.

The solution is found in devising some form of oscillatory circuit in which a condenser is involved and in which the wave-form approximates to that of the saw-tooth given in Fig. 121.

Here we are helped by the properties of inductive circuits, since a choke or a choke in combination with a condenser can be arranged to produce an artificial distortion in any wave, and can thus be made to give the required shape to the discharge curve. One or two oscillatory circuits, however, will give saw-tooth waves of their own accord, and among them a very good example is the "ticking grid" oscillator invented by Prof. Appleton. The circuit of this is shown in Fig. 126, and its action is the reverse of the circuits just described in that the condenser charges rapidly and discharges slowly and uniformly.

The circuit is the ordinary coupled valve oscillator with a condenser C in the grid circuit. Across the condenser is a shunt resistance R. shown dotted in Fig. 126. The coils are tuned to oscillate at a high frequency.

If R is high, when the circuit is oscillating the condenser C charges up and makes the grid of the valve negative with respect to the cathode. The anode current falls and the oscillations cease. The condenser now loses its charge by leakage through the resistance at a rate depending on the values of C and R. As soon as the condenser is discharged, the grid potential falls and the anode current rises.

The circuit then commences to oscillate again and the condenser re-charges. A true linear discharge of condenser can be obtained by using a diode in place of the resistance R as shown by D in Fig. 126, but if the amplitude of voltage change is sufficiently small it is linear for reasons which have been discussed previously. The circuit requires a valve amplifying stage to produce sufficient voltage change on the deflector plates.

The circuit can be synchronised by applying the signal through a condenser or transformer in the anode circuit of the valve. This circuit is a neat one and illustrates the type required for producing satisfactory scanning potentials. The output voltage is very low, however, but this is inevitable in most oscillatory circuits.

AN APPLETON CIRCUIT

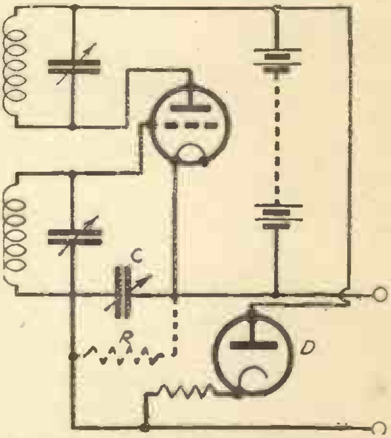


Fig. 126—"Ticking grid" oscillator, which gives approximately saw tooth impulses by the periodic discharge of a condenser

The Multi-Vibrator. Another important oscillatory circuit which forms the basis of most modern hard valve circuits is that known as the "multi-vibrator," so-called from its ability to oscillate at a number of frequencies, each of which is a multiple or sub-multiple of the fundamental frequency.

USEFUL FOR TESTING

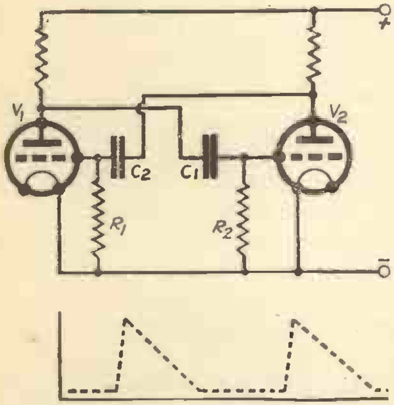


Fig. 127—The "multi-vibrator" is an oscillator giving saw-tooth wave impulses at any desired frequency. It can also be used as an oscillator for test work

The circuit, which is shown in Fig. 127 is really a two-stage resistance coupled amplifier in which the output from the second valve is fed back to the grid of the first. The action is as follows: Suppose that the anode current of V2 is momentarily increased by a small amount, such as is caused by a fluctuation in emission. The drop in the anode resistance increases, and the potential across the anode of the valve falls. This fall is communicated to the grid of the first valve by the coupling condenser C2, and the anode current of V1 also falls, but by a greater amount than the increase in the current of the valve V2.

The anode potential of V1 will therefore rise, and this rise will be passed on to the grid of V2 by the coupling condenser C1. The increase in grid potential of V2 causes a further rapid increase in anode current, which is handed on in turn. Eventually the grid of V1 becomes so negative that the anode current in V1 ceases and C2 is left fully charged.

It now discharges through the leak R1 at a rate determined by the values of C and R. The grid becomes less and less negative until the current commences again in V1. We now have the cycle of operations repeated, except that in this case the valve V1 is the originator of the rise in anode current.

The condensers C1 and C2 are alternately charged and discharged, and the resultant wave-form of potential in the grid circuit is that shown below the diagram. By changing the grid leak for a pentode the curve can be made more equal to the desired saw-tooth.

Space does not allow of further consideration of the details of this interesting circuit, but it is an excellent one on which to base investigations into scanning circuits, besides forming a useful and flexible laboratory oscillator. Suggested values for the grid leaks are 2-3 megohms, with 100,000 ohm anode resistances. The coupling condensers must be adjustable for varying frequencies, and can be from .025 to .0005 mfd. Synchronising to a given impulse can be accomplished by a transformer connected in the anode circuit to which the incoming signal is applied.

G P.

Chapter 16

SOME PRACTICAL CIRCUITS

HARD VALVE CIRCUITS—OPERATION OF THE CIRCUIT—BALANCED DEFLECTION—PENTODE-FED "SOFT" BASES—RESISTANCE FEEDING — SYNCHRONISATION CONTROL—FILTERING THE FREQUENCIES — HARD TIME BASE CONTROL—USING BOTH WAVE FRONTS — THE PICTURE CONTROL — RATCHETING — A COMPLETE "SOFT" TIME BASE—COMPLETE "HARD-SOFT" BASE—THERMAL DELAY SWITCHING — THE VON ARDENNE CIRCUIT — THE AMPLITUDE FILTER—EXCITING THE CATHODE-RAY TUBE—EFFECTS OF COMPONENT BREAKDOWN—THE POTENTIOMETER CIRCUIT—CHECKING SCANNING SPEED—DRY RECTIFIER CIRCUITS—SCREENING, EARTHING, AND GENERAL CONSTRUCTION—RECTIFIED A.C. FOR DIRECT-HEATED TUBES.

In previous chapters on the cathode-ray methods of television reception the basic facts necessary for the understanding of the action of the cathode-ray tube, and the means whereby it may be made to provide television reception have been given.

It has been seen how focusing of the tube is attained, and how it is made to scan. Methods of providing that scanning have been discussed, and you are now familiar with something of the ingenious arrangement of valves that constitute the time base. Some of the snags that are met with in time base theory have been mentioned and explained, but up till now the practical aspects of the case as apart from the purely theoretical have not come under discussion.

In reading this chapter we want you to place yourself in the position of a would-be cathode-ray television set builder, with no fixed idea as to exactly what type of receiver you will construct, but awaiting some details from which you may decide on your final design. And as regards that final design you are concerned at present only with the cathode-ray section, and not at all with the radio side.

We do not propose here to provide that design in its entirety; later in the book we give fuller details for the construction of an up-to-date television receiver; but we want in this chapter to bring forward some typical practical circuits, and to discuss some of the practical snags and pit-falls that may be encountered, and the ways of obviating them. Not faults that may evidence themselves in a finished receiver, but rough places that have to be ironed out before the actual construction is commenced—" paper " faults, if you like to call them such, that will evidence themselves in the analysis of the circuit.

You will already have realised that linearity in a time base is essential for undistorted picture reception. The question that remains is what sort of circuit, or circuits, can be used to ensure reasonably good linearity. Note that we say reasonably good, for perfection in television has not yet been reached, though it is now in such a stage as to make it really well worth while. After all, it does not matter if the scan is not truly linear so long as the eye does not perceive the curving of the lines.

Hard Valve Circuits. As you have seen, there are two main types of valve circuits that can be used in time bases, the " hard " and the " soft " (or gas-filled discharge) types. The two can be used separately or mixed if desired, and we shall discuss the various varieties as we go on. For the moment, let us consider the hard base of which Fig. 128 is an example. Here it will be noted is

THE COSSOR HARD TIME BASE

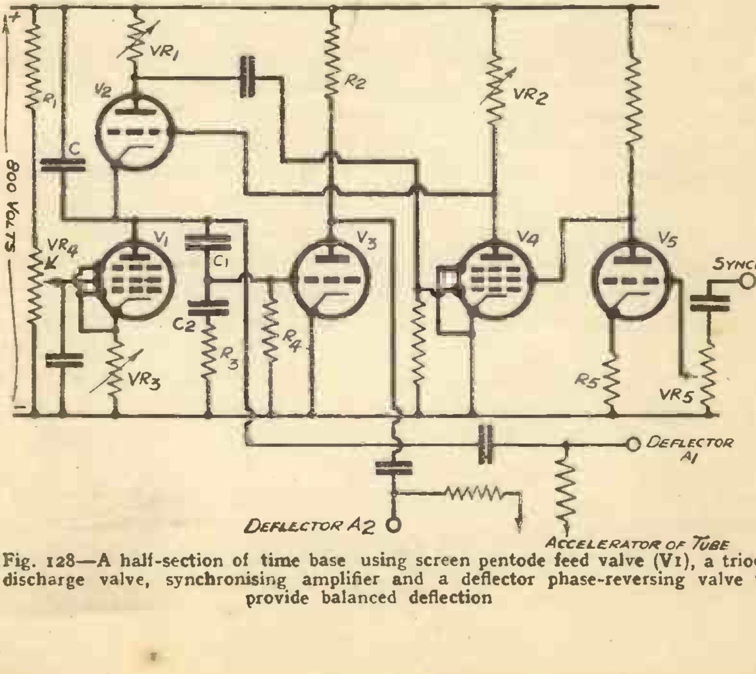


Fig. 128—A half-section of time base using screen pentode feed valve (V1), a triode discharge valve, synchronising amplifier and a deflector phase-reversing valve to provide balanced deflection

only half the base, the other half can conveniently be one of the "soft" variety, or it can be another hard base.

It will be noticed that the half-base is shown operating one pair of deflectors (the other half would operate the other pair), a balanced deflector method of coupling being provided to prevent any defocusing of the beam due to the deflector voltage variations. The defocusing is prevented by keeping the mean potential of the plates at the same value as that of the last accelerator (2nd or 3rd, dependent on make of tube) of the tube—that is, at earth potential. (It must always be fully realised in cathode-ray work that when we speak of "earth" potential we mean that of the actual earth, and not that of the cathode of the tube, which may be some 2,000 or 3,000 volts, or even more, below earth.)

Operation of the Circuit. You will have read about hard time bases in the previous chapter, but we will just run through the operation of this particular circuit so that you will obtain an idea of what is required of the various parts used.

We will assume that the time base consists of two similar bases, of which that shown in Fig. 128 is the line frequency half; that is, it has to scan at 6,000 per second for 240 line scanning.

Assume also that the voltage from the H.T. and L.T. power pack attached to H.T. positive and negative is ready to be applied, and that the heaters of the valves are alight and the valves warmed up. With no H.T. on of course nothing happens. Now switch on the H.T.

At once current flows through R1 and VR4 providing the required screen grid voltage of the pentode V1. It is ready to pass anode current, but cannot owing to the fact that the triode valve V2 is in series with its anode, and as this valve is not operating nothing happens in the V1 circuit.

All this takes thousands of times longer to tell about than it does to happen, but this is what is actually in progress. Suppose the condenser C, which is the condenser which is to be charged and discharged to form the sawtooth waveform of scanning (about .0005 mfd for 6,000 lines) is at the moment uncharged.

Thus there is no potential across it, the top and bottom plates are at equal potentials, and so there is no potential across V2 and that valve is dormant.

But there is a potential across V4, and the normal anode current for that type of valve is flowing, providing a large drop of potential across VR2. As the grid of V2 is connected to the anode of V4 it must be at a potential very much less than the top of VR2, and therefore of the anode of V2. And, as we have seen, the cathode of

V2 is at the same potential as the anode (for the moment), therefore there is considerable negative grid bias on V2.

But C will not stay uncharged all the time. It begins to charge, and its rate of charge is controlled by the impedance of V1, controlled either by VR4 or VR3, or by both. And as C charges so the potential applied to the deflector A1 changes.

Eventually C reaches such a state of charge that the potential between the plates, and therefore, across the anode and cathode of V2, reaches such a point that the grid bias of that valve is overcome and anode current begins to flow. This causes a voltage drop, a sudden one as current commences, across VR1, which impulse is applied via the condenser to the grid of V4. This immediately affects the anode current of V4, for the grid becomes negative, and the anode current of V4 drops. This drops the grid bias on V2, which immediately results in a further increase of anode current in V2. This increase is transmitted to the grid of V4 as before, and results in a further drop of bias on V2 due to the drop in anode current of V4. And so it goes on. The effect is cumulative, and in no time there is a huge current flowing through V2 and C is discharged.

As soon as this has happened we reach the first state of affairs—an empty condenser—and the whole process starts over again.

Now, in practice, the whole system depends on the skill and accuracy with which the resistances VR1 and VR2 are adjusted. VR2 controls the length of the scan and VR1 controls the speed of the triggering, and therefore the flyback. If this is too slow there is a nasty tracer across the screen.

VR2 naturally must be to some extent interdependent with VR1, and of course we must not forget that VR4 or / and VR3 have to be adjusted to give the speed of charge of the condenser C. But VR1 is the most tricky resistance to adjust, and it must be of value to suit the valve and of easy and accurate adjustment.

Of V3 and V5 we have said nothing at the moment. We will deal with them now. V5 is merely a synchronising amplifier which impresses on the grid of V4 the synchronising signal, thereby controlling the static state of V4. When a synchronising impulse arrives it is transmitted to V4 which thereupon reacts on V2, causing that valve to " spill over " immediately and discharge the condenser. But we shall discuss synchronising more fully later.

Balanced Deflection. V3 is a little more obscure in its action. It is a valve that is not necessary to the operation of the circuit in itself, but it assists in the quality of the results by providing the balanced deflection voltage that we have mentioned.

Actually it provides a " copy " of the deflecting voltage (which is, of course, A.C.) that is obtained from the condenser C, but the " copy " is rotated in phase through 180 degrees owing to the action of the valve stage (Fig. 129).

HOW THE PHASE REVERSER WORKS

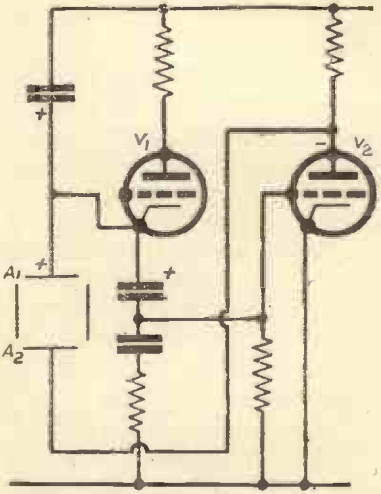


Fig. 129—V1 is the discharge valve, and the impulses from its associated condenser are applied to V2, which " copies " the impulses in its anode circuit but with a phase change of 180 degrees

The condenser potentiometer C1 and C2 provide that the value of signal applied to V3 shall be of the required strength. It is desirable to apply a proportion of $\frac{1}{m}$ of the total voltage, where M is the effective amplification of the valve V3 as used in the circuit. Thus the output strength of the signal is equal to the signal applied by C to the deflector plate A1, but is in opposite phase. This signal is applied to plate A2. Thus the plates are symmetrically held throughout the whole operation of the time base, for it must be remembered that the other half of the time base is carrying out just the same impulse feed but at a different frequency, namely 25 times per second.

As a matter of fact, the need for deflector balance is not quite so great in the case of the second half of the time base, for distortion on the frame scan is not so likely to upset things as it is on the line scan.

As we said before, we can use a soft base on the frame or picture scan, though it is felt that a hard base is essential for the line scan, although even here the comparatively slow fly-back may be troublesome. The frame scan need not be so strictly linear as the line scan and the soft (gas discharge tube) base is quite adequate.

This remark rather libels the soft base, however, which can be made quite linear enough for 240 line television reception, and we shall deal with that type of base next.

Pentode-Fed " Soft " Bases. We do not propose to go very deeply into these for they are so similar to the resistance-fed bases in their fundamentals that little need be said. The main features of the pentode-fed base have been dealt with in the previous chapter.

In practice, this type of base, with its gas discharge relay valve, has the great advantage over the resistance-coupled type in that it is easier to get the scan practically completely linear, and that a high voltage on the base is not required. Against this the cost is greater for valves, and in some ways the construction is not so straightforward, for the cathode of the gas-filled relay is not at earth potential, and the biasing arrangements are not so easy to obtain.

THE RESISTANCE-FED CIRCUIT

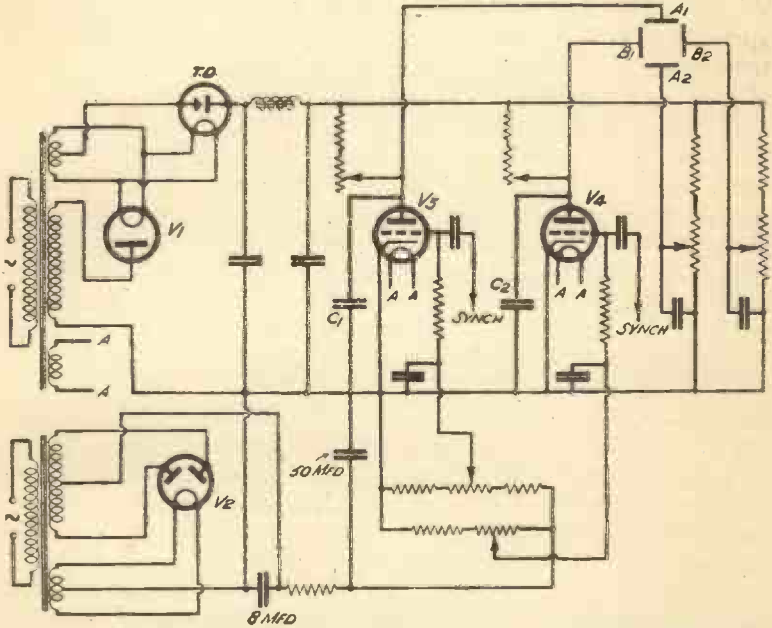


Fig. 130—A fundamental, but quite workable time-base circuit using resistance-fed gas-filled discharge tubes. The synchronising is applied to both the grids of these valves (V3 and V4) and bias is provided by the valve V2. The H.T. rectifier circuit has a thermal delay switch in series with the positive feed (TD) to allow the discharge valves to heat up before they have H.T. applied to them

An example of a fundamental pentode-fed gas discharge time base is shown in the previous chapter, Fig. 123.

Resistance Feeding. The simplest type of time base, and one of the most economical, is undoubtedly the resistance-fed soft type. It is comparatively easy to construct, and though it has the disadvantage of requiring from 1,000 to 2,000 volts, the current required from the power pack is quite small, from 10 to 15 milliamps, and the actual scanning part of the circuit requires only two valves, preferably of the helium-filled type.

Though the resistance-fed time base is such a simple piece of apparatus there are many points to be watched in the practical application of it, and there are several modifications worth considering.

In Fig. 130 you see a simple practical time base with resistance-fed thyratrons. It is shorn of some of the refinements that go to make the perfect base, but it is quite practicable, and we shall discuss and add the refinements as we go along.

The first thing to notice is that there is no synchronising locking link between the two thyratrons, such as is used when 30-line television is being received. There is no need for such a link, for two separate synchronising signals are sent out on high definition systems and the two thyratrons are fed with the individual synchronising impulses from the valve filter scheme. Of this we shall have more to say later.

The practical features of the circuit as regards component values are given on the diagram, but at the outset it is perhaps advisable to say that though the power pack of the base is shown on the same diagram, it is usually better to include it with the pack for the tube and to screen the whole lot from both the time base itself and from the cathode-ray tube. A.C. ripple is fatal to cathode-ray tube working, and no trace of it can be allowed either in the anode circuits of the time base or in the tube circuits. Neither must there be any chance of the tube being brought into the range of A.C. field such as surrounds the power transformers. Half-wave mercury vapour valves are used for the cathode tube power pack, and for the time base rectifier in order to give good regulation, but a full wave ordinary rectifier is employed to give the bias voltage. This valve is shown as V3 on Fig. 130.

One of each pair of deflectors (A1 and B1) are fed from the two thyratron anodes and therefore get their deflecting voltages from the condensers C1 and C2, while the other two deflectors, A2 and B2, are fed with H.T. from a potentiometer across the time base H.T. This potentiometer scheme must be variable in order that the deflector voltages can be varied to place the scanning frame in the right position on the tube.

Note the voltages of the condensers. These must be of good make and of sufficient voltage margin, otherwise leakage and possible breakdown of the time base may occur. Leakage will result in uncontrollable scanning and breakdown in cessation of the scanning process, with the result that the spot on the cathode screen will become stationary, with disastrous results to the screen.

Note that C1 and C2 should be able to withstand the maximum H,T. voltage. This is because while the condensers are not likely to get that amount applied across them, there is just the chance, should the thyratrons fail to strike at any time, due to any fault in the valves or in the associated components or connections. In that event the voltage across the condensers C1 and C2 would reach maximum and if they were not of high voltage working they would break down.

As we said before, Fig. 130 is quite a practical circuit, but it can be improved upon.

Synchronisation Control. The elements of synchronisation have been dealt with in the previous chapter, and it now remains to be seen how the synchronising impulses can be used to control the cathode-ray time base. It depends on the type of time base exactly what control can be obtained over it by the synchronising signals.

These signals consist of a line and a frame or picture signal, the former sent out at the beginning (or end) of every line scan and the latter at the beginning (or end) of every picture scan.

THE SYNCHRONISING IMPULSES

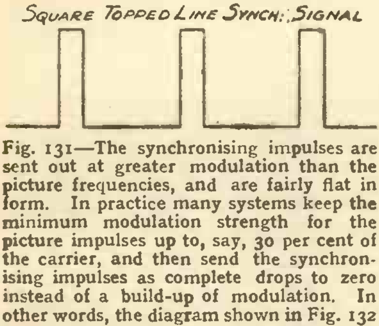


Fig. 131—The synchronising impulses are sent out at greater modulation than the picture frequencies, and are fairly flat in form. In practice many systems keep the minimum modulation strength for the picture impulses up to, say, 30 per cent of the carrier, and then send the synchronising impulses as complete drops to zero instead of a build-up of modulation. In other words, the diagram shown in Fig. 132 is turned upside down, the dotted line denoting the 30 per cent line. The result on the synchronising valve is, of course, the same—a powerful A.C. impulse

The signals are shaped something like the figures shown in Fig. 131 where it will be seen that the line signal actually comprises an impulse in the positive direction followed by an impulse in the negative, there being a slight passage of time between the two. The picture signal, such as is used by the Baird process, is of similar shape, but "lasts" longer, or in other words the top is longer and the time passage between the upward and downward impulse is greater.

Actually the line signal can be looked upon as two separate signals in reverse potential, one being a positive impulse and the other a negative. The picture signal can be looked upon in the same way, but it is not necessary so to do for the timing of the picture part of the time base is not nearly so delicate as that of the line portion.

There are other types of synchronising impulses but they are all pretty much alike as regards the line signal. In the case of the Cossor system, however, the picture signal differs in that the continued absence of a picture synchronising signal actuates the picture scanning device, and this absence obviates the necessity for the line and picture signals to be separated in the time base to avoid false synchronising.

It is likely that the method used for broadcasting television in this country will for some long time use the type of signal that demands the separate line and picture impulses, and so we will concern ourselves with the practical aspects of those methods here.

AN ANODE BEND FILTER

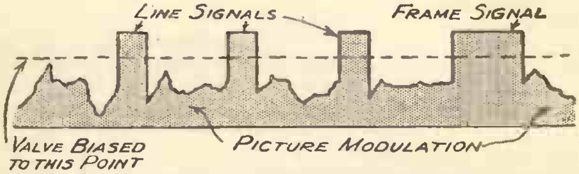


Fig. 132—The anode bend rectifying valve is used to cut off the peaks of the synchronising impulses and to reject the picture frequency impulses to give clean synchronising control

First of all, we will deal with the resistance-fed soft time base and the possible method of applying the synchronising signal to that type of base.

Fig. 132 indicates one method where the picture and synchronising impulses go out together, with the synchronising impulses at a greater strength than the picture modulation.

By cutting off the tops of the modulation we can collect the synchronising impulses only, and then pass them on to our time base as desired.

The results of this cut off by an anode bend valve is shown in Fig. 133 where it will be seen that only the synchronising impulses have caused anode current change.

APPLYING SYNCHRONISING THROUGH THE ANODE BEND FILTER

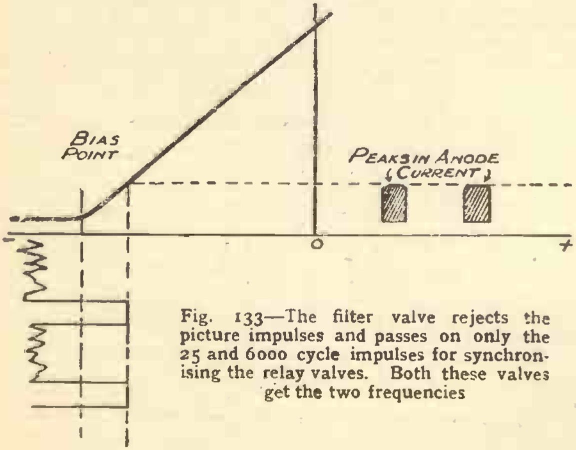


Fig. 133—The filter valve rejects the picture impulses and passes on only the 25 and 6000 cycle impulses for synchronising the relay valves. Both these valves get the two frequencies

Filtering the Frequencies. This valve is shown in Fig. 134 where after the biased filter valve there are two valves with tuned-anode circuits so arranged to peak at 25 cycles in the one case and at 6000 cycles in the other. The result is that we get practically pure 25 and 6000 cycle positive impulses from the respective anodes, and can apply them to the two relay valve grids separately, as shown.

This is somewhat costly in practice, for it means two extra valves and the ordinary anciliary components as well as the specially tuned filters for the anode circuits, while the time base is apt to assume large proportions and a by no means low cost.

The anode potential for the valves can be obtained from the main anode feed for the time base, and the grid bias in the case of the filter from the bias valve circuit or from the potentiometer scheme where the H.T. is tapped so as to allow bias to be derived from it.

The two amplifier valves with the tuned anode circuits can be self biased. But it should be remembered that we do not need a large voltage synchronising signal, and so the valves employed in the filtering system must be volume-controlled well down. As a matter of fact they can be all anode bend biased to reduce H.T. consumption if desired, the two tuned valves being adjusted to the anode bend point, while the main filter valve is biased very much past the bend.

THE TUNED FILTER SYSTEM

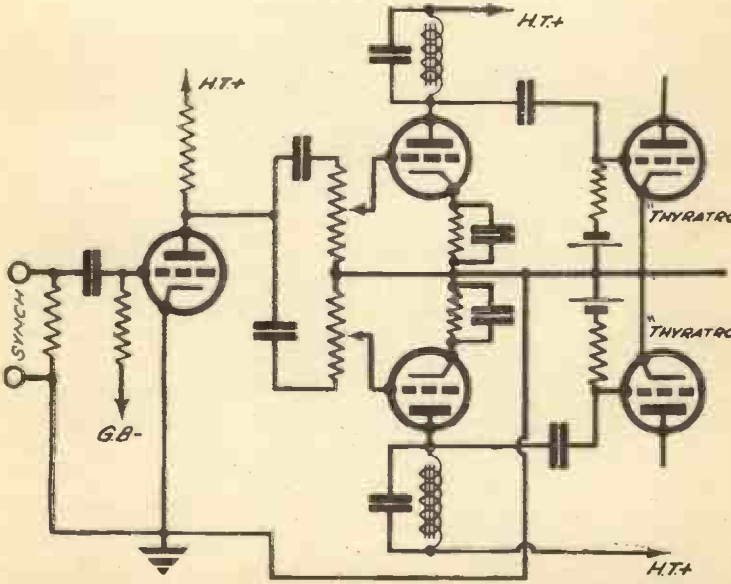


Fig. 134—A tuned filter is useful to clean up completely the synchronising impulses before applying them to the time base valves. In practice it is essential to obtain clear-cut synchronising control

As the synchronising voltage required to operate the time base is only a matter of a few volts, each of the tuned valves should be capable of being volume controlled, while to ensure good results the bias of the main filter-valve should be adjustable, and the radio input can also be controlled if desired.

Such are the main practical requirements of synchronising circuits in soft time bases.

Hard Time Base Control. The use of the synchronising signals in the hard type of time base is somewhat different for with the type of triggering used, it is possible to make the two " sides " of the synchronising line impulse control not only the firing of the discharge system, but also the moment at which it shall build up again.

To understand this it is necessary that we regard the synchronising impulse (for the line scanning) as consisting of first a positive impulse and then a negative one.

It has become the practice to make the synchronising impulse correspond to zero carrier amplitude, and for the proportion of synchronising signal amplitude to that of the total signal (synchronising plus picture) to be about 1 to 3. A smaller ratio would mean that the proportion of transmitter power available for the modulating of the picture itself would be unreasonably restricted.

But as the synchronising waveform is very unlike that of any outside interference that may be encountered, there is little difficulty in keeping it pretty clear of other impulses as regards its effect on the time base.

As we can look upon the synchronising signal, with its flat top, as two signals we can arrange for the time base to be doubly controlled as stated above, and that is done in this manner.

The time base has been developed by Puckle and Bedford of Cossor and the vital portion is shown in Fig. 135. We have explained how a circuit of this nature operates as regards the production of scanning (see Fig. 128), but in Fig. 135 you will see some extra valves.

As you know, V1 is the charging valve, C1 is the condenser to be charged and discharged, V2 and V3 form the discharging circuit, and V4 is the synchronising valve.

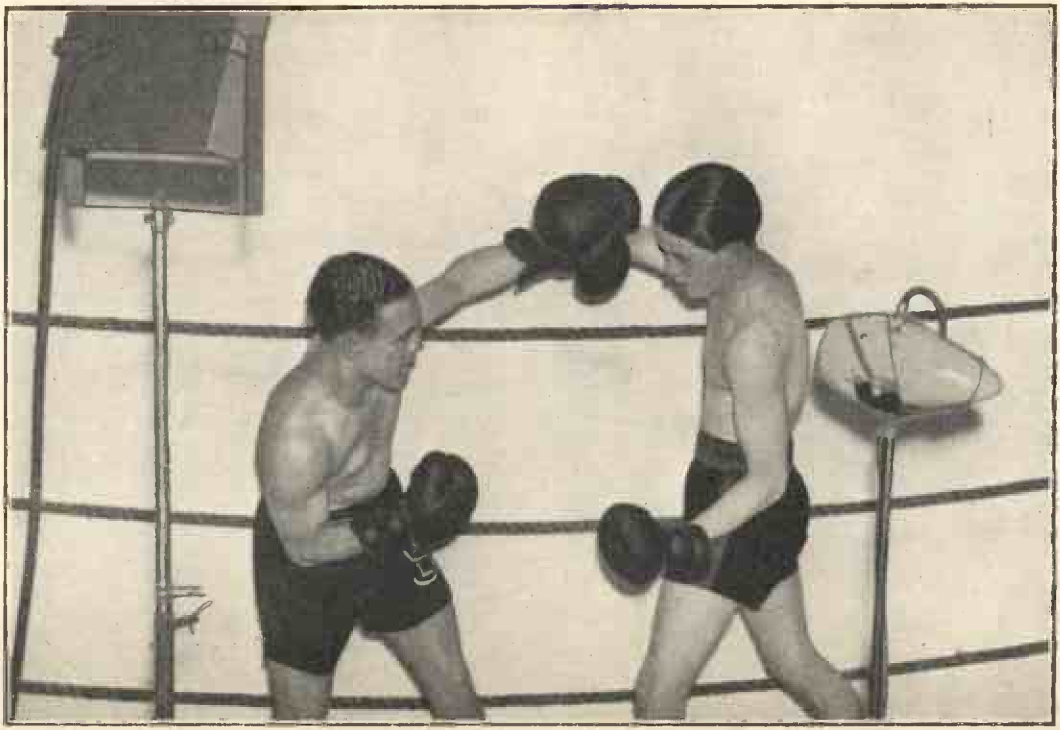
Now when a positive synchronising impulse arrives (that is, the rise of the flat topped impulse) it is applied to the grid of the valve V4. This results in a negative impulse being applied to V3 via the condenser C3. This again results in a much amplified positive impulse being given to V2 which at once sets the discharge circuit in action.

THE SIMPLICITY OF LOW DEFINITION TELEVISION RECEPTION IS ILLUSTRATED BY THIS AMATEUR-CONSTRUCTED VIEWER. COSTING ONLY ABOUT TEN SHILLINGS IT OBTAINS ITS DISC-DRIVE BY MEANS OF A FRICTION COUPLING WITH A GRAMOPHONE TURNTABLE

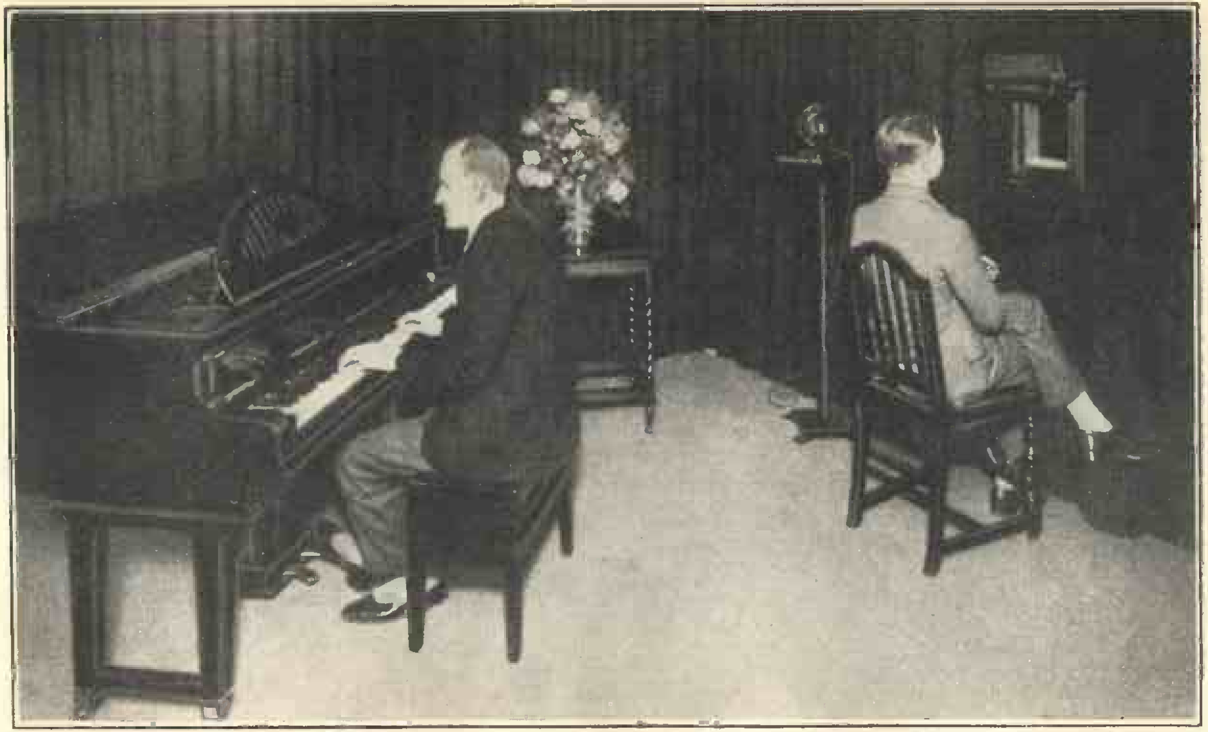
Plate 35

Plate 36

AN ENGINEER OPERATING A TELEVISION CONTROL PANEL AT BROADCASTING HOUSE



THE EXPERIMENTAL TELEVISING OF A BOXING MATCH FROM THE CRYSTAL PALACE. THE PHOTO-ELECTRIC CELLS CAN BE SEEN ON THE LEFT AND THE MICROPHONE ON THE RIGHT. THESE HAVE BEEN BROUGHT INTO THE RING IN ORDER CONVENIENTLY TO INCLUDE THEM IN THE PHOTOGRAPH



ONLY CLOSE-UPS WERE POSSIBLE DURING THE EARLY TELEVISION BROADCASTS, AND THIS PHOTO SHOWS A VOCALIST SITTING BEFORE AN APERTURE BEHIND WHICH WAS THE SCANNER

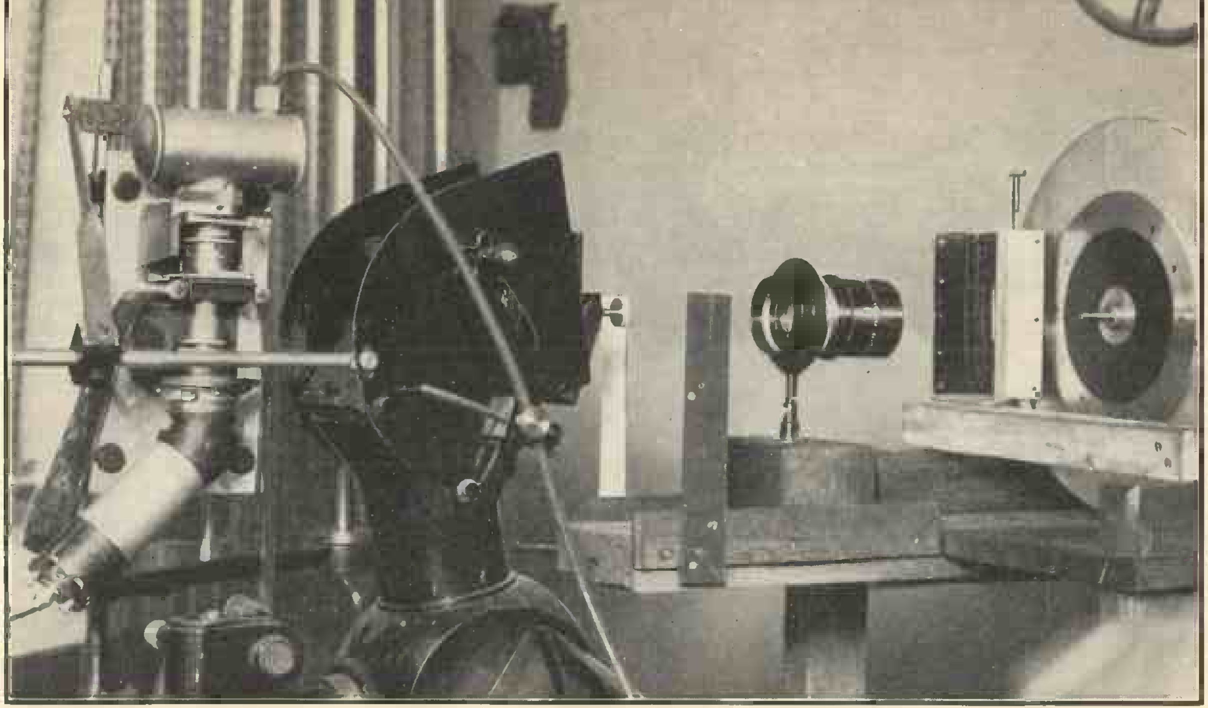
A BAIRD ENGINEER WITH THREE TYPES OF THE ELECTRON MULTIPLIER WHICH IS USED IN CONJUNCTION WITH FARNSWORTH'S ELECTRON CAMERA

A MANNEQUIN PARADE IS A TELEVISION PROGRAMME ITEM WHICH SHOULD PROVE HIGHLY ATTRACTIVE TO LADY "LOOKERS"

Plate 40

A FIRST
BRITISH CATHODE-RAY
TELEVIEWER

A "POPULAR WIRELESS" TECHNICIAN DEMONSTRATING THE FIRST SUCCESSFUL BRITISH CATHODE-RAY RECEIVER. THIS TUBE WAS OPERATED ENTIRELY BY BATTERIES



AN EARLY FILM TRANSMITTER USED BY BAIRD. PLATE 44 ILLUSTRATES ONE OF THE LATEST FILM-TELEVISION OUTFITS

Plate 42

SYNCHRONISING THE HARD BASE

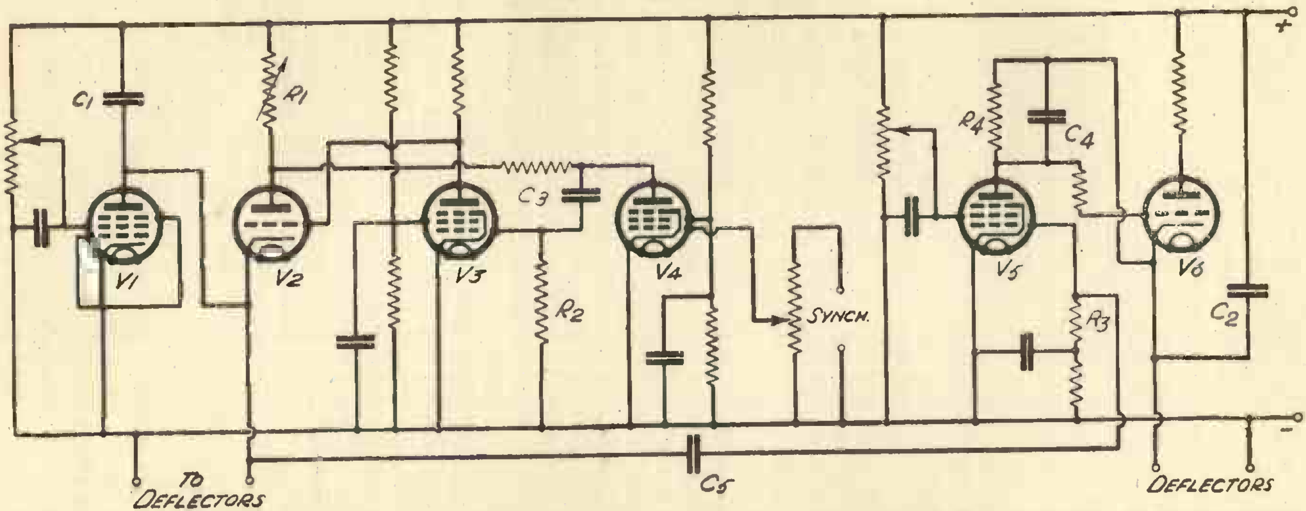


Fig. 135—Here is a circuit showing a complete hard-time base in skeleton form. V4 is the synchronising valve which controls the discharge and charge , No picture synchronising impulse is required for this base as ratcheting is employed for the control of V5-V6, the ratcheting being fed to V5 from V2 via the condenser C5. In practice the valve V2 has a diode included as Fig. 137, the diode being used to control the feed current and to lock the multi-vibrator circuit

Now when the potential across C1 has fallen, owing to its completion of discharge, the valve V2 becomes inoperative, as you have already seen. On this state it is non-conducting.

But consider. As soon as the positive impulse on V4 has been passed on to V2 it has reached its flat top, and so no impulses are reaching V4 which, for a fraction of a second, is inoperative. During this time the discharge through V2 has commenced and this, by virtue of the resistance R1 applies a negative pulse to the grid of V3. This pulse reduces the anode current in V3 and, therefore, makes the grid of V2 positive, thereby increasing the discharge current and again increasing the negative state of V3. The effect is cumulative, of course.

When the discharge has ceased V3 again starts to pass anode current and the grid of V2 becomes negative, thus allowing no anode current, but allowing the condenser C1 to start charging up again ready for the next synchronising trip.

Using Both Wave Parts. That is with the resistance R1 in circuit. Now assume that this resistance is set to zero, and we are again at the state of V4 when the positive signal has been passed, and we are awaiting the " drop " from the flat top of the synchronising impulse to give us the negative pulse.

The positive pulse on V2 has caused anode current to flow and the condenser to be largely discharged in a big rush. But as there is no resistance R1 in the anode circuit of V2 (R1 having been set to zero) there is no linking effect between the anode current flowing in V2 and the grid of V3. Thus when the synchronising pulse stops the current in V2 anode circuit stops and the circuit becomes inoperative and inert.

Now what happens? The negative pulse from the same synchronising signals falls on the grid of V3. This at once makes the grid of V2 very negative owing to the making of V3 grid positive, and the consequent increase in that valve's anode current.

The impedance of V2 goes up and immediately the circuit is set for the commencement of the charging business again. And at every synchronising impulse the same negative pulse will set the grid of V2 to the same degree of negative bias so that the charging will inevitably start at the correct time from the correct static position.

In practice it is possible to use this double synchronising pulse only if the signals are strong and are not interfered with. Where weak field strength is encountered, or interference is rife, then it is sometimes better to use the circuit with some value of R1 in circuit so that the time base sets itself rather than depend on the negative impulse to reset it.

But what of the picture scanning part of the base ? What happens there ? Referring to circuit 135 again, we turn to V6, which is a gas-filled discharge valve. You will remember that we said earlier that there was no need to use a hard base for the second portion of the system, and that a soft base would do for the picture scan part.

It will be recalled from Chapter 15 that in practice the time base is always set so that it will normally fire later than the synchronising signals arrival, and that the arrival of this signal causes the spill-over to come just before the " natural " time.

The Picture Control. Returning to the valve V6. This has to be supplied with a picture control signal, but in this circuit the normal impulses are not used.

The condenser C2 is charged through the valve V5 and the resistances R4. It will be noted that the grid of V6 is taken to the anode of V5 through the grid resistance, and is joined to cathode through the resistance R4. The grid bias potential for the valve V6 is built up across this condenser by the voltage drop across R4 caused by the charging current in the anode circuit of V5.

Now the grid of the charging valve V5 is fed by means of the differentiating circuit C5 R3 from the cathode of V2.

A differentiating circuit is one that can provide a potential output whose waveform is the differential of that of the applied potential. In the form shown it consists of a high impedance condenser with a low value of resistance in series with it.

Now, if the impedance of the resistance is negligible in comparison with the reactance of the condenser at the frequency of the impulses applied to it, it can be reckoned that the instantaneous current flowing through the condenser will be equal to that which would flow were the resistance not present.

The instantaneous current flowing through the condenser is directly proportional to the rate of change of potential across the condenser which in this case is great. Therefore, the instantaneous voltage across R3 is also equal to the rate of change of voltage across the whole circuit.

A circuit of this nature is very useful, for it enables very sharp impulses of high amplitude to be fed from one circuit to another. In this case we feed impulses derived from the line scanning fly-back potential to the grid of the feed valve for the picture scan condenser.

Thus, every time a line is completed an impulse is applied to V5 and the anode current of that valve is given a sudden increase. This results in the condenser C2 being given definite charging increases at fixed moments—during the fly-back of the line valve—and at the same time the grid bias of V6 is maintained.

Here it must be realised that the condenser C4 is a leaky one, owing to the resistance R4, and the length of time the bias potential across C4 lasts depends on the time factor of that circuit C4 R4.

At the end of the picture scanning, that is, when the end of the picture is reached and the last line has been completed, there is a pause in the proceedings while the picture synchronising signal is transmitted. During this time the grid bias of V6 leaks away and the valve discharges.

Ratcheting. The process is known as "ratcheting," and it is completely independent of the picture synchronising signal. Thus the scheme is suitable for any type of television transmission, whether of the sort that sends out a picture-synchronising signal or not.

On the cessation of the line fly back impulses and the cessation of impulses on the grid of V5 the latter valve ceases to provide anode current because it runs into grid current and so biases itself beyond the cut-off point. Thus there is no time lost in the leaking away of the bias for V6, and the firing of that relay valve provides a very quick fly-back of the cathode spot to its point of origin.

When the line scanning starts again the valve V5 is again affected and anode current flows, bias is resumed for V6 and the ratcheting process starts again.

A Complete "Soft" Time Base. In Fig. 136 is shown a complete soft time base circuit with its connected cathode-ray tube excite unit.

The approximate values are given for an anode potential on the time base of 1500 volts, obtained from the half wave rectifier V1, which it will be seen has a thermal delay switch in series with the H.T. positive side. This thermal delay switch is essential to allow the valves in the time base, especially the gas relay valves, to warm up before the H.T. is applied. Besides avoiding strain on the valves it prevents the condensers across those valves getting the full voltage.

As a matter of fact, it is advisable to use condensers in the positions just mentioned with working voltages of 1500 volts so that should the relay valves ever refuse to strike the condensers will not be broken down by having too high a voltage thrown across them.

All the valves, including the cathode-ray tube, are heated by A.C., the valves, with the exception of V9, taking four volts. This valve requires two volts and this value is applied by the secondary of the transformer which is tapped so as to allow four volts, or rather a little under four volts, for the thermal delay switch and two volts for the rectifier. This is a mercury vapour valve giving 2600 volts at about 5 milliamps.

A COMPLETE CATHODE-RAY CIRCUIT

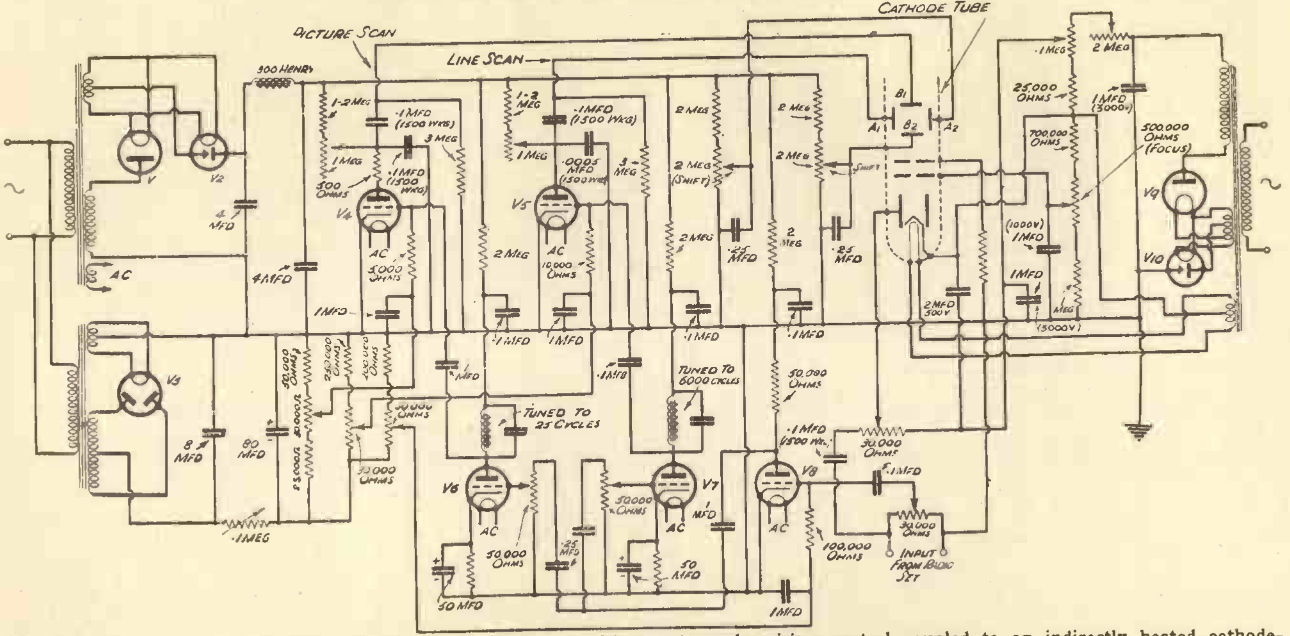


Fig. 136—A resistance-fed gas-filled discharge tube time base with tuned synchronising control coupled to an indirectly heated cathode-ray tube. Note the two thermal delay switches, that of V10 being delayed to trigger after V2 so that the time base is set in operation before the spot of the cathode tube is produced. The values given are those that are best in most cases, but individual valves require slight adjustments, and changes may have to be made. V6, 7, and 8 should be of the steep slope type, such as the AC2HL. V6 and V7 are well biased and with their anode currents cut down by the use of high resistances in the anode circuits and in the cathode circuits. V8, of course, is set to its anode bend point

All the one mfd. condensers in this part of the circuit must be of 3000 volts working type to avoid any chance of a breakdown.

But to return to the other end of the circuit. It will be noticed that the grid bias is applied by a separate valve, V3. This is fed from a separate transformer, and the various voltage taps are taken off the potentiometer network shown. This network feeds the whole of the bias for the time base circuit.

Complete "Hard-Soft" Time Base. The circuit shown in Fig. 137 is that developed by Cossor and incorporates the methods of synchronising and ratcheting described earlier in this chapter. The values are given for the valves mentioned, and though the rectifier valve seems to be overrun it will not suffer harm on that account for the wattage taken from it is not excessive.

V5 is an interesting valve. It is a modulating valve for the shield of the tube, and is set so that the synchronising signal just drives the valve into grid current, and therefore the signal strength or amplitude that corresponds to black always occupies the same position on the grid volts anode current curve.

H.F. losses in the anode circuit of V5 must be kept down or definition will suffer, and sometimes an H.F. choke of the value of some 2000 microhenries can be inserted in series with the anode resistance to give a "lift" effect.

If you will refer to circuit Fig. 128 you will see that a compensating valve for the deflector feed was used, a valve that gave balanced deflection by the application of reversed phase potential to the opposite deflector plate to the one fed from the discharge valve. In Fig. 137 two such valves are employed, one for the line scan and one for the picture scan. They are V6 and V9.

Initial shifting control for placing the spot in the proper position to start with is carried out by the two potentiometers RA and RB. Note that the bias resistance for the gas filled relay valve V8 is variable, and this has to be set to give the best results of timing on that valve's discharge.

Thermal Delay Switching. We should explain why the thermal delay switch on the cathode-tube exciter circuit is set at less than four volts on its heater. The reason is that we do not want this relay switch to go over until that in the time base has made contact. We then ensure that the time base has commenced its scanning operations before the cathode-ray tube has started, and therefore the spot on the tube screen is never allowed to come to rest. If it were allowed to start from rest each time the set was switched on, remaining at rest while the time-base warmed up, the screen would eventually be badly burnt at the place where the spot started each time.

A COMPLETE HARD BASE CIRCUIT

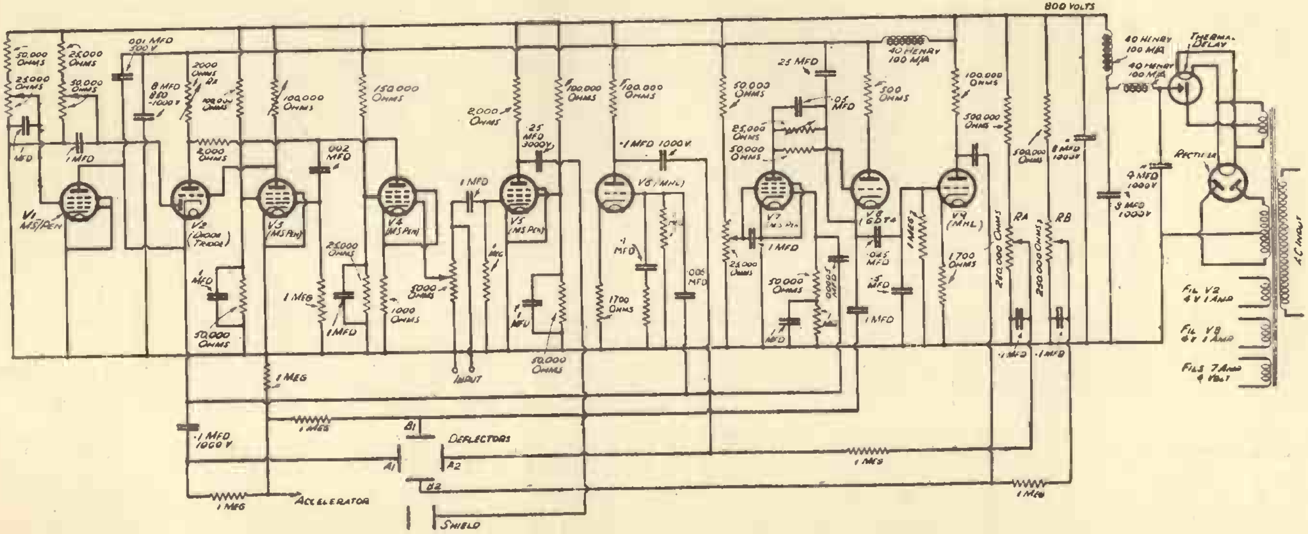


Fig. 137—All the valves are hard with the exception of V8, which is a gas-discharge valve. Ratcheting is employed to allow the picture scan periods to be controlled regardless of whether a picture synchronising signal is sent out or not. Phase reversing valves, V6 and V9 are used for two deflectors, while the other pair is controlled from the cathodes of the discharge valves V2 and V8. The position of the frame on the tube face is controlled manually by the shift potentiometers Ra and Rb

Thus it will be realised that the need for thermal delay switching is a very real one. It does not matter what sort of thermal delay is used, either the vacuum or the ordinary mechanical type can be employed, but it is essential that the difference of potential between the winding or filament that carries the heating current and the switch portion be kept at a minimum.

The two Figs. 138 and 139 show two sorts of thermal delay switches and either of these can be used with equal success.

As will be seen, both contain heating elements which are close to a metal contact bar which bends towards another contact as the heat increases. Eventually the bending metal makes contact with the other side of the switch and the H.T. circuit is made.

THE VACUUM DELAY SWITCH

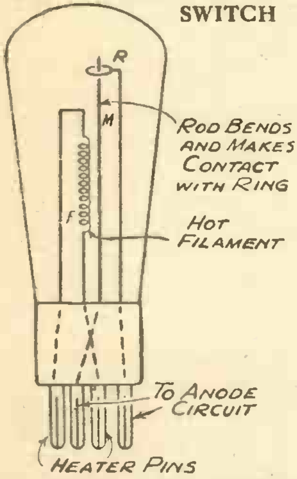


Fig. 138—As the filament F heats it causes the metal rod M to heat, by conduction, and this rod bends until it touches the ring R. Owing to the vacuum there is no arcing at point of contact

THE NON-VACUUM SWITCH

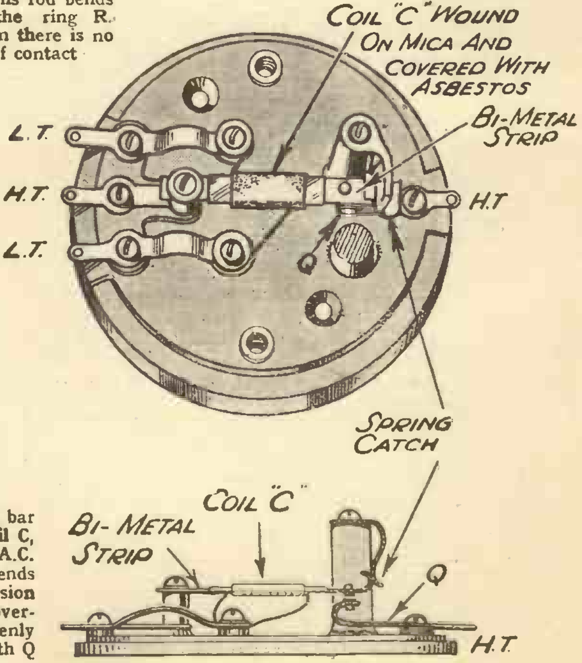


Fig. 139—A bi-metal bar is heated by the coil C, through which passes A.C. As it heats the bar bends against a spring tension which it eventually overcomes and suddenly snaps into contact with Q

The Von Ardenne Circuit. Before we discuss some of the requirements of the actual components used in a television scanning circuit let us have a brief look at one of the most up-to-date circuits

A RESISTANCE-FED TIME BASE DEVELOPED BY MANFRED VON ARDENNE

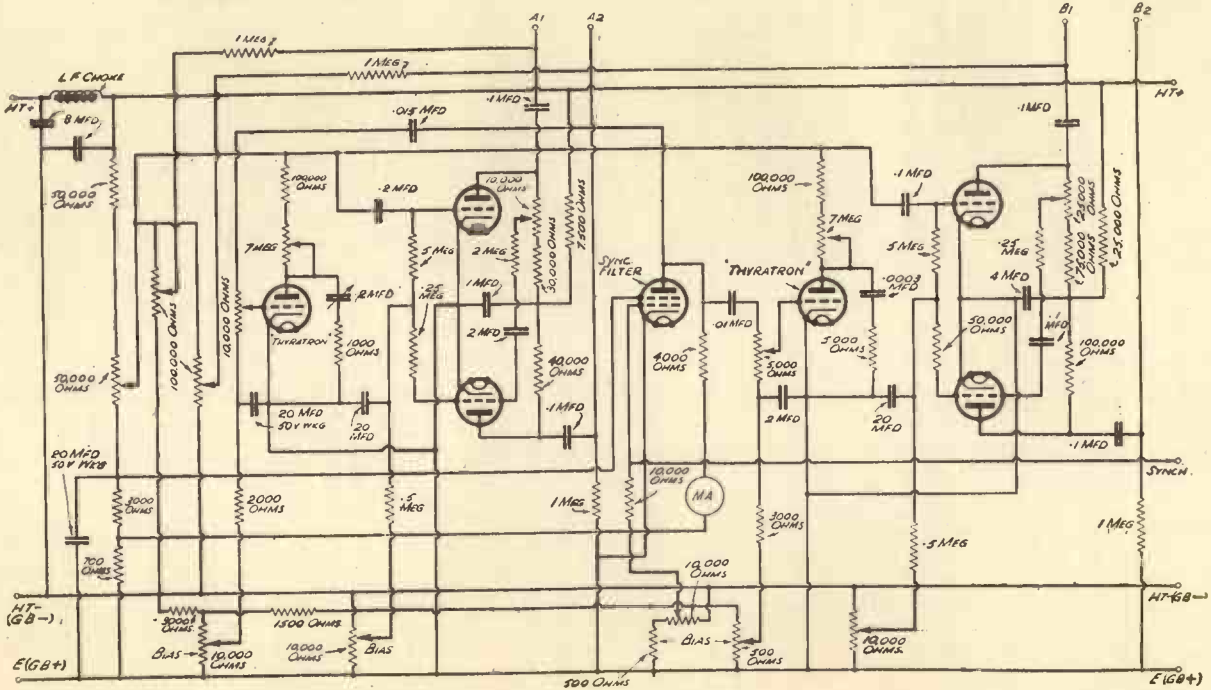


Fig. 140—This time base is based on that used by the famous Continental research worker, Von Ardenne. It uses push-pull deflection control and a synchronising filter which limits the amplitude of the synchronising impulses to give a constant strength

using gas-filled discharge valves and a form of paraphase push-pull deflector coupling.

This circuit (Fig. 140) is very similar to that just discussed, except for the deflector coupling and the method of synchronisation. The time base is of the resistance-fed type, and the well known thyraton valves are used. Grid bias is obtained by using a potentiometer scheme across the main H.T. circuit of the time base, instead of a separate valve for bias being employed.

The usual control of speed and length of scan is used, but the outputs of the two relay valves are taken to push-pull schemes. In our diagram we have translated the circuit for use with two sets of static deflectors, but Von Ardenne uses one static pair and one magnetic pair.

Balancing of the deflection is obtained by means of the variable resistances across the anode circuits of the push-pull valves, and it will be seen that the output of one of these valves is fed into the grid of the other in each case to obtain phase reversal. It will also be noticed that one of each pair of plates is earthed, that is, it is at the same potential as the main accelerator of the cathode-ray tube.

This potential is then decreased at A.C. (at 25 and 6000 cycles per second for 240 lines and 25 frames per second), and at the same time the potential of the opposite deflector in each pair is increased by the same amount at the same time. Thus completely balanced deflection is attained with no variation of focusing as occurs when a strong D.C. potential is applied. (See previous chapter.)

The Amplitude Filter. The synchronising scheme is interesting in that an amplitude filter is used. This valve is the screen grid valve shown in the centre of the diagram, and it provides the same strength of synchronising impulse throughout any transmission.

Von Ardenne has arranged his valve so that the whole of the anode current-grid volts curve is on the left of the zero bias line, and, moreover, by placing the screen of the valve at a higher positive potential than the anode he has altered the curve.

The result is something like that shown in Fig. 141, and it will be

THE AMPLITUDE FILTER VALVE CURVE

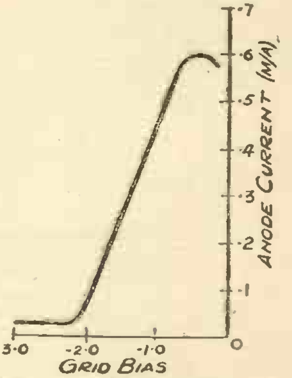


Fig. 141—By adjusting the screen voltage to be higher than the anode voltage a curve like this is obtained. It falls totally to the left of the zero grid volts line

seen that the curve goes up and then bends over before the positive bias point is reached. Thus it is possible so to adjust the valve that the synchronising impulses are amplified up to the limit of the valve and then any further amplification is cut off, resulting in a series of impulses of the same voltage value. Naturally the amplification is small, but a large output voltage is not required, so that the smallness is no disadvantage. Incidentally, the valve takes very little anode current, a milliammeter of maximum 1.5 milliamp being sufficiently large to show when the valve has been correctly adjusted.

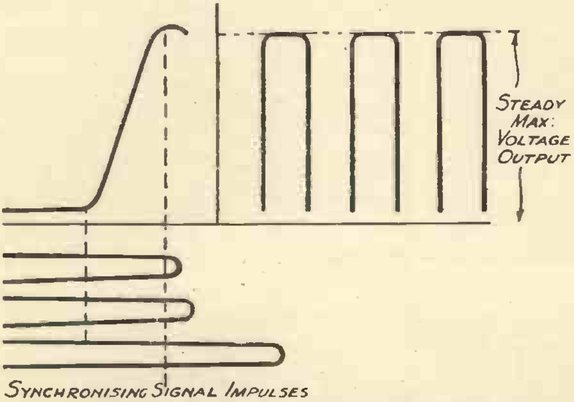

HOW THE FILTER WORKS

Fig. 142—Synchronising impulses are voltage levelled by the action of the amplitude filter used by Ardenne with the result that the impulses fed to the time base are always constant in strength

The resulting synchronising impulse action of the valve is illustrated in Fig. 142, where it will be seen that though the input may differ the output voltage is always the same, provided of course that the initial impulse is of a workable "size." The synchronising input voltage is always set to be sufficient to load the valve, of course.

Exciting the Cathode-Ray Tube. We have already seen the circuit of a typical cathode-ray tube H.T. supply, but there are one or two points concerning tube excitation in practice that should be said. Whether valve rectifiers or dry rectifiers are used the same precautions should be used.

We will first of all illustrate an exciter circuit using a valve rectifier, but when we come to the use of dry rectifiers it will be seen that the same remarks will hold good.

Let us study Fig. 143 and see what precautions have to be taken to ensure the best operation. The circuit is designed to give from 2600 to 4000 volts according to the tube. Let us assume that we are using the former voltage, such as is required for the Ediswan AH type of tube.

That means that across the condenser A is a steady 2600 volts, while across C is something a little under 2600, according to the position of the slider of P. Condenser B has to deal with a maximum of 2600 less the bias of the shield of the tube, namely 2540 volts or so. All these condensers are of 1 mfd capacity, and have to be of the oil immersed or petroleum jelly impregnated variety, and able to withstand 2600 volts. The nearest to that voltage on the market are the 3000 volt working condensers.

Effects of Component Breakdown. This voltage business is extremely important, for consider what happens if, for instance, condenser C should break down. Immediately the shield of the tube would be earthed, and a full 2600 volts in respect of its cathode would be applied. The result is a spontaneous electron explosion of the cathode of the tube due to the complete removal of bias and of the space charge.

Condenser E should also be of the high voltage type, for this couples the shield with the radio input potentiometer, which is

SAFEGUARDING THE TUBE

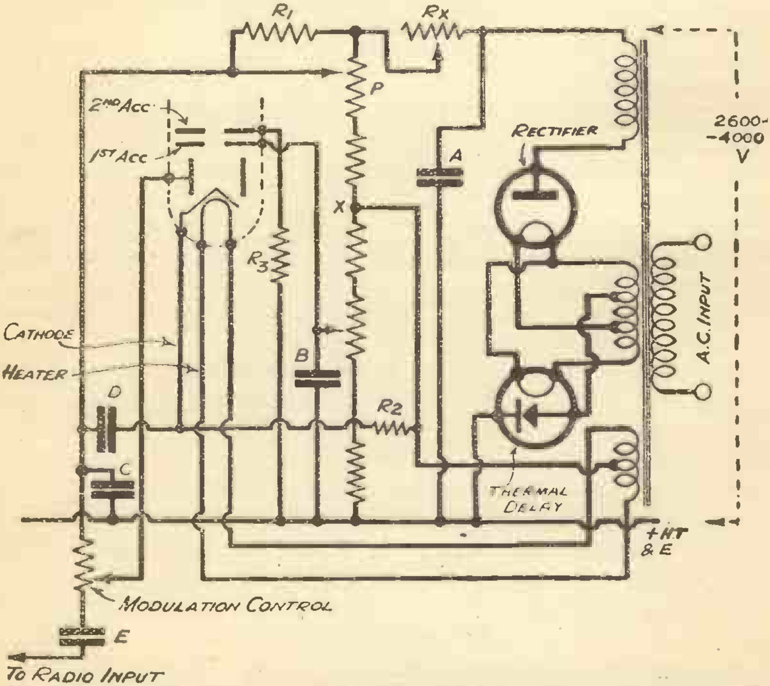


Fig. 143—A typical cathode-ray tube exciter circuit showing points where breakdown may occur with disastrous results to the tube. Condensers A, B, C, and E should be of the high-voltage type

earthed at one end. Therefore breakdown of this condenser would have the same effect as a breakdown of C.

Condenser D is not likely to break down, for it is subjected to a mere 60 volts or so, and can obviously be of the 250 working type, with every safety. The only danger that can threaten D is a break in the potentiometer chain between point X and the negative end, when of course D would be subjected to the full 2600 volts and would not survive that attack on its insulation.

But it is not of the condensers that we are thinking ; they are comparatively inexpensive : it is the cathode-ray tube which is jeopardised if any of the condensers mentioned breaks down, and a new cathode-ray tube costs anything from eight guineas upwards.

The Potentiometer Circuit. That break in the potentiometer chain we have just mentioned shows the necessity for good resistances and potentiometers that will always provide good contact between the windings and the sliders.

The wattage of the resistances for a 2600 volt exciter need only be one watt, but it is essential that the connections between resistances be well and truly soldered, and that the action of the potentiometers be smooth and certain in contact.

For instance, should the slider of potentiometer P fail to make contact at any time with its winding the bias on the screen of the tube would be removed. You already know the result of that. To obviate such a mishap it is a good plan to fix a resistance R1, as shown, so that the bias cannot be removed by failure on the part of the slider of P.

The resistance R2 is suggested as a safeguard against too sudden an electron rush should the bias of the tube be removed, and while the resistance would not save the life of the tube it might slow things down sufficiently to allow the operator to switch off quickly, in time to save the cathode from " explosion."

The resistance R3 is used partly to have a similar effect by keeping a check on the accelerator current, and partly to insert a resistance between the accelerator and earth to reduce the danger of A.C. interference, which is sometimes noticed when the accelerator is connected direct to earth.

Checking Scanning Speed. The actual operation of a time base will be dealt with when we come to the use of the cathode-ray receiver described in chapters 19 and 20, but we should here mention the automatic scanning speed indicators that have been suggested which will tell at a glance, or by sound, when the gas-filled relays or other discharge valves are firing at the right speed.

By coupling a tuned circuit, either direct or via a valve system with the anodes of the discharge valves, it is possible to actuate a tuned reed or other device to denote when the right speed is achieved.

It is difficult to get a very sharp point, because the tuned circuit into which the impulses from the discharge valve are fed is liable to oscillate at its natural frequency regardless of the applied frequency, because the impulses are not sine wave in form but are sawtoothed. Thus the circuits are shock excited, and there is a danger of their oscillating after the impulses have died out.

Fig. 144 shows a circuit that shows promise, but much work remains to be done before perfection is achieved. The impulses from the discharge valve V are fed to two tuned circuits after they have been fed through a valve which acts as a buffer. The tuned circuits in the case of high definition television are arranged for 25 or 6000 cycles per second, and a separate system of filters and indicators is used for each section of the time base; that is, one for the picture scan and one for the line scanning.

CHECKING SCANNING SPEED

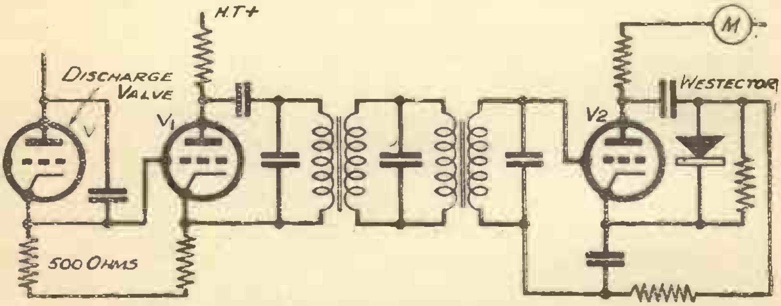


Fig. 144—A circuit that is under investigation for denoting the arrival of a scanning circuit at the correct speed. Tuned filters in conjunction with the valves give visible indication on the meter M when the correct speed is reached

Following the tuned circuits is a valve which is coupled to a rectifier scheme that provides bias for the valve. The effect of this scheme is that as soon as the impulses from the discharge valve V arrive in the tuned circuits, through the valve V1, they affect the grid of V2. This modulates the anode current and causes A.C. to be developed across the rectifier scheme. This causes a bias to be applied to V2, and the amount of this bias is in accordance with the degree of the anode current change. As this depends on the strength of the impulses we can see that the bias is proportional to the strength of the incoming impulses. It is best to arrange for the bias to be negative and to be increased on arrival of the impulses.

But the bias increase will cause a decrease of the steady anode current, so that the meter M will show at once the degree of bias that is being applied. Now, if the tuned circuits are selective enough very little effect will be had by the discharge valve impulses until they reach the periodicity of the tuned circuits, that is, the 6000 cycles per second that we require for the line scanning.

At this point the effect will be very great, and the valve V2 will be operated strongly. The result will be a strong bias application and therefore a very large deflection in the needle of the milliammeter in the anode circuit.

Thus we can see at a glance when the discharge valve is running at the right speed, a very great help, especially in experimental work. With complete sets the need for such a device is not quite so great, for the " speeds " of the base are roughly set by the values of components, and once found, it is not difficult to adjust to the same points again.

Dry Rectifier Circuits. Instead of valve rectification it is possible in cathode-ray work to use dry rectifiers, as shown in Fig. 145. Here we see a full time base circuit with exciter unit and tube using the special long rectifiers (type H) which Westinghouse have developed for high voltage work.

Half-wave rectification is used for the bias, but we consider that probably full-wave rectification would be better and more free of hum. A.C. ripple is the bugbear of all cathode-ray television circuit designers, and every precaution must be taken to prevent any suspicion of hum in the scanning circuits or in the tube supply. But we shall have more to say about that later.

The circuit of Fig. 145 is one that has been evolved by the Westinghouse Company, and we reproduce it together with the values for low definition television. It is, of course, a fundamental circuit, and requires modification before it is ready for use on high definition transmissions. The synchronising link is shown as used for low definition work, and would have to be changed for high.

Screening, Earthing and General Construction. The putting into practice of the circuits shown is not a difficult matter if it is remembered that we must keep out any A.C. ripple, and that we are dealing with high voltages.

In the first place good chokes and condensers are essential, and 300 henry chokes in the time base are usually used. Resistance here must be kept down within reasonable limits, however, for the regulation of the H.T. supply of the time base is a basic feature of the scheme. If the H.T. voltage fluctuates much as the discharge valves fire, then the circuit is useless.

A DRY RECTIFIER CATHODE-RAY CIRCUIT

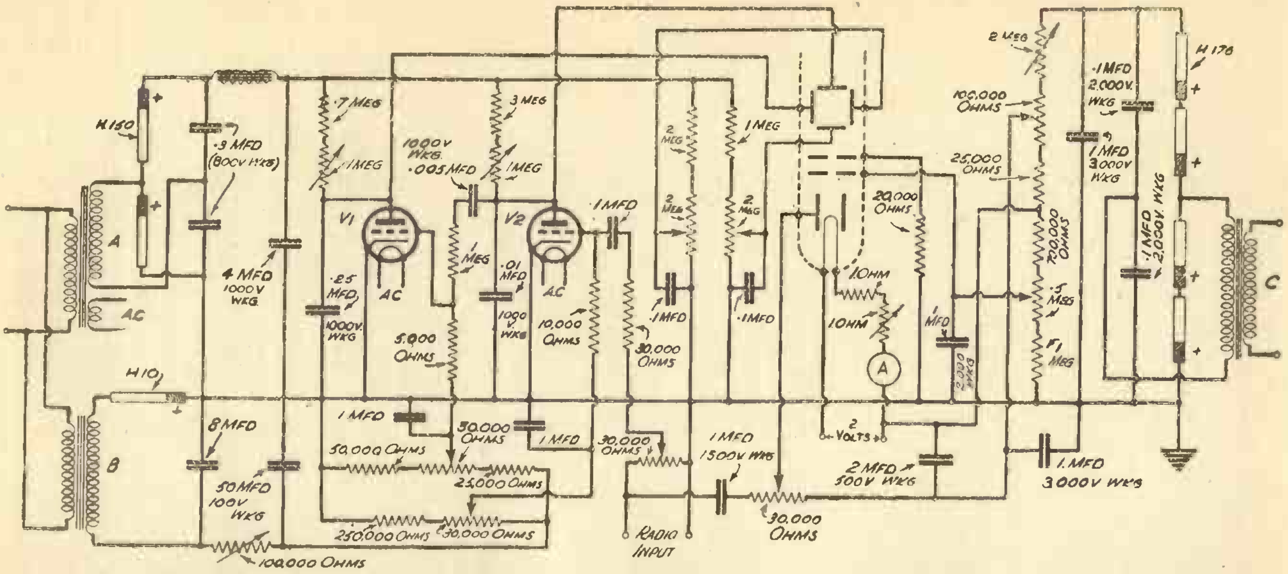


Fig. 145—All the rectification in this circuit is carried out by means of Westinghouse dry rectifiers. The smoothing choke should not be of less than 300 henries, and special dry rectifier transformers should be used for the mains supply. Voltage doubling circuits are employed for the time base and exciter H.T. and half-wave rectification for the grid-bias supply to the time base. The coupling between V1 and V2 grid and anode is used for low definition reception. For high definition work this coupling is removed and separate synchronising feeds are arranged. Gas-filled relays are used for the discharge valves V1 and V2

It is probably best to build the mains part of the time base and the whole exciter in one unit, screening the whole to prevent the spread of the A.C. fields from the transformers and to protect the worker from shock. The screen must be earthed, of course. And here we must stress one point. That earth is the same connection as the accelerator of the cathode-ray tube, that is, it is 2000 or more volts above the cathode of the tube. In other words, the cathode is 2000 volts or more below earth potential and therefore must not be touched while the set is working. As a matter of fact, it is advisable, most strongly advisable, that no part of the receiver interior be touched while the set is switched on. Such an action might not be fatal, for the current available is small, but the voltage is extremely high and a very nasty shock would result.

It is therefore up to the constructor of the television receiver to ensure that, once the set has been built and the screen or iron box fitted, no high voltage part can be touched.

And in the construction the high voltage will necessitate especial care about such things as spraying of flux when soldering, and insulation between terminals and on panels. Wipe every trace of flux off the parts soldered, and the neighbourhood, for sprayed flux layers may cause bad leakage and sparking. Good ebonite should be used for panels and terminal strips. Composition is useless.

Systoflex can be used for wiring but must not be allowed to touch any points of high potential. In other words, do not let wires touch each other, even if they are covered wires. The insulation is not always good enough to stand the pressure. Everything should be air spaced where possible.

The time base section can be built in another metal box, and it can have the tube enclosed with it, if desired. The power packs should be kept as far away from the tube as possible, connection being

REDUCING L.T. VOLTAGE DROP

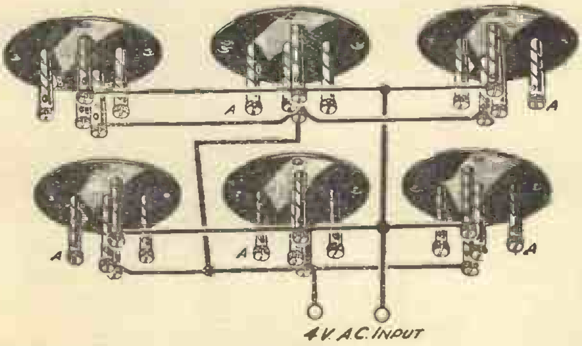


Fig. 146—The method of splitting the heater circuits to reduce voltage drop in the wiring. The feed is to the approximate centre of the circuit with branches feeding out on either side

taken by means of high voltage cable, such as they use on motor cars for the ignition. It is interesting here to note that Von Ardenne even screens the two sections of his time base from one another.

Remember, that in most designs there are several amps of A.C. flowing at four volts for the heaters, and do not invite failure by using thin wire for connecting the heaters together and to the power pack. It is best to use two parallel cables for the heater connection between power pack and the time base, and it also helps to group the heater connections on the time base to allow a splitting up of the current to reduce the voltage drop. This is indicated in Fig. 146.

All terminals for inter unit connections should be of the large safe type and should be mounted inside the can that will eventually be used to screen the unit. No terminal strips outside the screening boxes should be used. Do not "economise" in the manner of condensers. Use the best and use working voltages that are amply

A.C. SUPPLY FOR A DIRECTLY HEATED TUBE

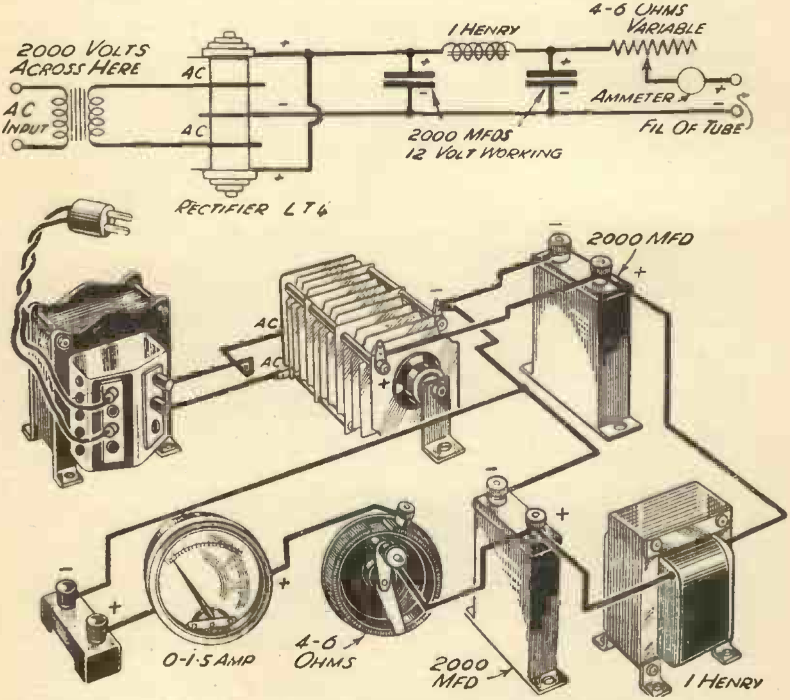


Fig. 147—A simple, but quite effective, circuit for the supply of L.T. from A.C. mains for the operation of a battery cathode-ray tube

safe. For 2500 volts or so use 3000 volt working, for 3000 volts use 4000 volt working.

Rectified A.C. for Direct-heated Tubes. Mains transformers should be of good make, for they have to be constructed to withstand very large voltages at A.C. If, in building a cathode-ray receiver, you decide to use a directly heated tube and to run it from A.C. via a rectifier, as shown in Fig. 147, remember that the secondary of the transformer is connected through the rectifier to the cathode of the tube and is therefore 2,000 or more volts below earth potential. Also remember that the primary of the transformer is at earth potential, for the mains are earthed on one side. Therefore, the transformer must be a good one, designed to withstand some 2000 to 4000 volts between primary and secondary, although it has to supply a mere 11 volts, perhaps, of A.C. for the L.T. rectifier.

And with a directly heated tube use a good control resistance for the cathode, and an ammeter reading up to 1.5 amp. The tube will require about 1 amp. at something like .4 volt.

The choke shown should be about 1 henry in inductance and not more than three or four ohms in resistance. It means a big choke, but that cannot be helped; the supply must be smooth and we cannot afford much voltage drop. The Westinghouse L.T.4 rectifier will do quite well, and two wet electrolytic 2000 mfd condensers complete the smoothing.

Finally, you may be tempted to build your time base and exciter units on metallised wood and to use the metal surface as a common connection for the earthed points. Do not do it. The metallising will not give a satisfactory contact—it was not meant for high voltage work—and it is best if you must use metal to use a " real " metal baseboard or chassis. Better still, do not use metal at all, use wood throughout. It is easier to work with and very much safer from the insulation point of view. It is remarkably easy to get short circuits when using a metal chassis with such high voltage wiring.

Solder every connection unless the terminal you intend to use is a large one capable of giving and retaining perfect contact. Then screw up with pliers to make sure it will never come loose. But never place more than one wire round any terminal. Where wires meet, solder them. Multi-wire connections under terminals are not safe, and safe connection in television is as important as safe insulation. You cannot risk having a vital wire coming undone.

K. D. R.

Chapter 17

SPECIAL TELEVISION WAVELENGTHS

THE FALLACY OF WAVELENGTH-THINKING—IMPOSSIBILITY OF USING EXISTING SETS—TECHNICAL DIFFICULTIES—VITAL DIFFERENCE BETWEEN ULTRA-SHORT AND MEDIUM WAVES—MEANING OF WAVELENGTH—RELATIONSHIP OF WAVELENGTH AND FREQUENCY—VISION AND SOUND BROADCASTING COMPARED—TELEVISION TRANSMISSION REQUIREMENTS—THE BROADCASTING FREQUENCY SPECTRUM—REASONS FOR SELECTION OF ULTRA-SHORT WAVES.

The fact that the inauguration of "pictures by the fireside" is a development that is both new and very far-reaching may perhaps justifiably be advanced as a reason for the comparatively high cost of the apparatus involved—at least, as far as the actual vision part of the outfit is concerned.

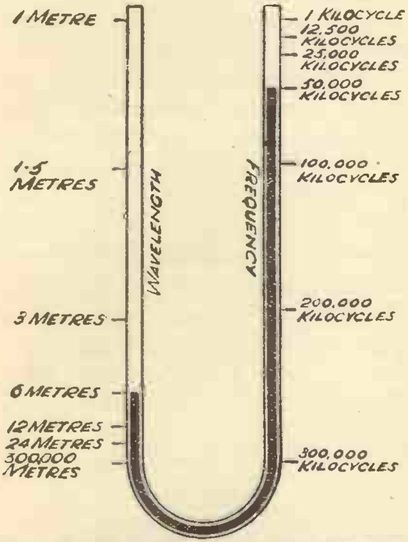
But why it should have been necessary to resort to ultra-short waves, and thereby to have incurred additionally the expense of a new receiver when the early recruits to this great new home entertainment will almost all be drawn from the ranks of the seven million listeners who already own broadcast sets, is a problem to which an answer does not so easily present itself.

That is mainly because through force of habit—and not on account of any theoretical advantage—we have become accustomed to thinking in terms of wavelength and not, as is the only way to obtain a true mental picture of the broadcast spectrum, in terms of frequency.

To the lay mind, there is nothing to distinguish the difference between, say, 7 metres and 300 metres other than that one is a very much shorter wavelength than the other.

Actually, of course, there is a very vital difference, and it is a fact that will become apparent as this chapter proceeds that but for the existence of ultra-short wavelengths, and the pioneering work that has already been done on them with the objective of the establishment of a broadcasting service, television in its present form would never have been possible.

At least, it would not have been possible unless Great Britain could have extended the medium band and persuaded every other station in Europe between 200 and 600 metres to have closed down, and even then British listeners would have had to be content with only one television programme, with nothing to supplement it other than on long or very short waves.



WAVELENGTH AND FREQUENCY

Fig. 148—The relationship of wavelength to frequency can easily be determined by mentally moving the "column of mercury" in this conversion "thermometer"

Impossibility of Using Existing Sets. Obviously, the idea is fantastic presented in that fashion, but for all that, that is what would have to happen before it would be possible for existing sets to be used for the reception of television programmes under the present system of transmission. Perhaps, in years to come, a new system will be devised, and we may then receive vision programmes on medium and long waves in much the same way that we receive ordinary broadcasting to-day.

But it is difficult to foresee a development in this direction for many years to come, if, indeed, at all. In connection with any aspect of television programmes as things are at present, the main thing to grasp is that it can be regarded as only supplementary to, and not in any way as superseding, our established service of sound broadcasting.

Apart, therefore, from the insuperable difficulties of radiating vision programmes on medium waves, it will be apparent that the establishment of a vision programme service could not, for very obvious reasons, be allowed to interfere with existing conditions.

Technical Difficulties. It should be made clear that the recommendations of the original Television Committee in favour of the use of ultra-short waves for vision broadcasting were not made, from the point of view of the man in the street, as the next best thing to the use of ordinary broadcast waves. Having regard to the technical difficulties on the transmission side, it was about the only recommendation that could be made, although as has already become apparent, it has called for infinitely greater skill in the design of apparatus for the receiving side, added to which is the increased difficulty of operation.

But that is a subject outside the scope of the present chapter. That the Committee was justified—indeed, that it had, in fact, no option in its wavelength recommendations—is what concerns us here, and in the explanation which follows it is hoped to convey the technical reasons which prompted the inauguration of Great Britain's first vision programme service on ultra-short waves.

In practically the whole of the explanations which follow, the arguments and considerations evolve around the velocity of ether waves and the consequent relationship of wavelength to frequency. And since it is of the highest importance that this formulae should be clearly understood, it might perhaps be more helpful to approach it with the aid of a simple analogy.

Vital Difference Between Ultra-Short and Medium Waves. Supposing two runners, one a tall fellow with long legs and the other a tiny chap with short legs, have both to run a mile in five minutes. It will be obvious that although their speeds will be identical, one—the little fellow—will have to take a lot more steps to cover the distance in the specified time than the runner with the longer legs and the bigger stride.

THE MEDIUM WAVEBAND

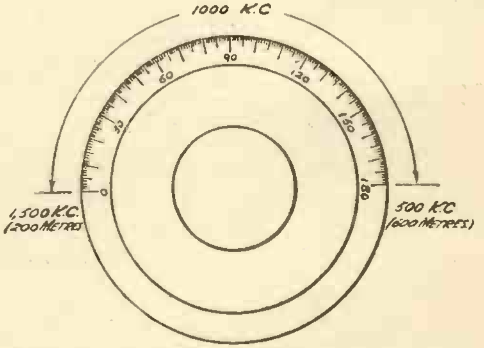


Fig. 149—Between the broadcast band extremities of 200 metres, which equals 1500 kilocycles, and 600 metres, corresponding to 500 kilocycles there is a frequency difference of 1000 kilocycles

And that is almost exactly what happens with ether waves. It may be accepted as an established fact that the velocity of ether waves is 300 million metres per second, irrespective of wavelength and frequency. Thus, if two stations are transmitting on totally different wavelengths, the ether disturbances caused by the transmitting aerials travel outwards into space at exactly the same speed.

Meaning of Wavelength. But these " ether disturbances " are in the form of waves, and the term wavelength is intended to convey the distance between the crest of one wave and the crest of the succeeding wave. And from this it follows that if one station is sending out waves 30 metres in length, and another waves of 3000 metres in length, then the shorter-wave station—like the little runner with the short legs—will have to make many more " ups " and " downs " to the second.

It is these " ups " and " downs " which account for the term frequency, and since both stations cover the same distance in the same time, the frequency may be arrived at by dividing the wavelength of the station into the velocity of ether waves. In the case of the two stations which we took as our examples—one on 30 metres and the other on 3000 metres—their frequencies would be (a) 300 million divided by 30, or 10 million cycles which, for convenience, we refer to as 10,000 kilocycles, and (b) 300 million divided by 3000, or 100,000 cycles (100 kilocycles).

Relationship of Wavelength and Frequency. From the foregoing explanation it will be apparent that as the wavelength, or the distance between crests, decreases, the frequency increases, and vice versa. This is shown diagrammatically in Fig. 148, and it is easy to establish the relationship between frequency and wavelength if you mentally move the column of mercury. For instance, if the column of mercury rises to the 3-metre mark on the left, then the drop on the right-hand side corresponds to the frequency having been doubled, and so on.

AN INTERESTING COMPARISON

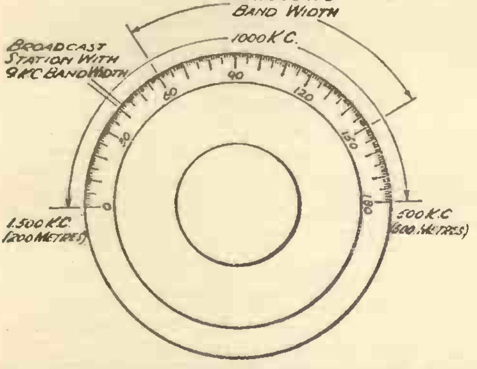


Fig. 150—An interesting comparison of the space taken by an ordinary broadcast station on the medium waveband and the space that would be taken by a hypothetical television station with a 500 kilocycle band width

Having, it is hoped, made the velocity-frequency-wavelength formulae quite clear, we can now progress a little further and consider it in relation to the requirements for ordinary broadcasting.

For all material purposes it may be assumed that the upper limit of audibility of the human ear is a frequency round about 9000 cycles, or 9 kilocycles. Some people are able to detect notes considerably higher than this, but that is not of any great consequence.

What really matters much more is the upper frequency limits of the various instruments that it may be required to transmit. The highest note of the clarinet, for instance, is nearly 3000 cycles, while the highest notes of the piano and the violin are in the neighbourhood of 4000 cycles. But the harmonic range of these and other instruments extends to very considerably above these figures, and so to obtain good quality of reproduction it is desirable to be able both to transmit and to receive up to at least 9000 cycles.

Nine thousand cycles, or nine kilocycles, is therefore deemed to be the minimum by which broadcasting stations can be separated, because otherwise, and for the following reason, stations are likely to interfere with one another.

Vision and Sound Broadcasting Compared. Although a station may be said to be transmitting on 300 metres, or 1000 kilocycles, it actually requires a little band of frequencies all to itself to allow for the rises and falls above and below the actual carrier wave frequency of 1000 kilocycles due to the frequencies that are being super-imposed upon it in the transmission. Thus, if a piano note corresponding to 3000 cycles is being transmitted, then at one instant of time the actual transmitting frequency will be 1003 kilocycles and at the next it will be 997 kilocycles.

EFFECT OF VISION WAVE

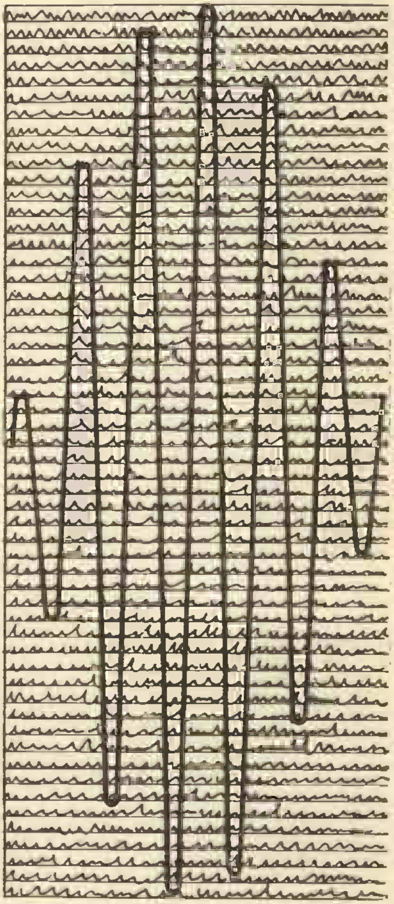


Fig. 151—This is what would happen to 55 medium wave stations if a 180-line station started up, and a 405-line transmission would swamp the band entirely !

It is for this reason that stations are separated by a 9-kilocycle band, but it naturally limits the number of stations that can be accommodated on any given waveband. Taking the case of the medium waveband as we know it to-day, and assuming, for the sake of simplicity, that the upper and lower extremities are at 200 and 600 metres, then between 200 metres, which is 1500 kilocycles, and 600 metres, which corresponds to a frequency of 500 kilocycles, there is a band of frequencies 1000 kilocycles wide. This is shown diagrammatically in Fig. 149.

In other words, if each station transmitting is to be allotted a band 9-kilocycles wide, then there is room for 1000 divided by 9, or approximately 111 stations, between 200 and 600 metres.

Television Transmission Requirements. It is in connection with the transmission of high-definition television that the real snag arises, for here, alas, to transmit and to receive pictures of high quality, each station requires a band all to itself not 9 kilocycles wide, but at least 500 kilocycles wide and more probably 1500 or 2000 kilocycles in width! And there is only a frequency difference, or, in other words, a band width of 1000 kilocycles between 200 and 600 metres.

If you examine Fig. 150 you will see what would be likely to happen to your tuning dial if 180-line television programmes were radiated on medium waves. Something like 55 stations would have to be wiped out to make room for one such "low" high-definition television station, and a 180-line station is given as an example because a 405-line station would not go in the band at all!

Some idea of the magnitude of the problem will be obtained from Fig. 151, which, while not strictly correct from the point of view of purely scientific representation, shows the effect of transmitting one television programme on the medium waveband. The small wavy lines represent stations—55 of them, and each with its little 9-kilocycle band all to itself. And all of these stations would have to close down to make way for the 180-line station depicted by the heavier line. Even this example is of necessity a hypothetical one, for the B.B.C. is, of course, using much higher definition than this, and there are not

"ULTRA-SHORT" ADVANTAGES

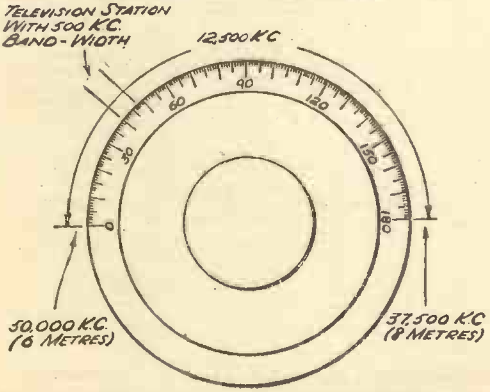


Fig. 152—Because there is a frequency difference of 12,500 kilocycles between 6 and 8 metres, a television "vision" transmission would occupy only a comparatively small part of the tuning dial

sufficient stations between 200 and 600 metres to show the effect of their transmission upon existing broadcast stations!

From the first, therefore, all thoughts of using the medium waveband for the transmission of television programmes was right out of the question. And on long waves the difficulty would be even greater, for the frequency decreases as the wavelength increases.

The ultimate recommendation of the Television Committee that vision programmes should be radiated on waves below 10 metres was prompted by the fact that it is the only part of the frequency spectrum where there is room for any number of them.

The Broadcasting Frequency Spectrum. For instance, on the basis of 2000-kilocycle separation, between 6 metres, which is 50,000 kilocycles, and 8 metres, which is 37,500 kilocycles, there is a frequency difference of 12,500 kilocycles and there would therefore be room for 6 stations. Moreover, under these conditions, each station would only occupy a comparatively small part of the tuning scale.

The availability, so to speak, of the frequency spectrum in so far as broadcasting is concerned is depicted in the accompanying table. The most interesting thing about this table is that it shows that something like 75 stations, each with the required band width of 2000 kilocycles, could be accommodated between 1 and 2 metres, and the reader may wonder why, in these circumstances, this " band " was not selected for television transmissions.

1 Metre=300,000 Kilocycles 2 Metres=150,000 Kilocycles	150,000 K.C. frequency difference	÷ 2000 K.C. = 75 stations
6 Metres = 50,000 Kilocycles 8 Metres = 37,500 Kilocycles	12,500 K.C. frequency difference	÷ 2000 K.C. = 6 stations
100 Metres = 3000 Kilocycles 200 Metres = 1500 Kilocycles	1500 K.C. frequency difference	÷ 2000 K.C. —
200 Metres = 1500 Kilocycles 600 Metres = 500 Kilocycles	1000 K.C. frequency difference	÷ 2000 K.C. —
1000 Metres = 300 Kilocycles 2000 Metres = 150 Kilocycles	150 K.C. frequency difference	÷ 500 K.C. —

On purely theoretical grounds, there is everything in favour, and nothing against such a project. But the whole difficulty lies in the impracticability of using these waves for the establishment of a broadcasting service.

Reasons for Selection of Ultra-Short Waves. Obviously, the reception-reliability factor must enter prominently into any considerations governing the choice of a suitable wavelength, and the technical transmission and reception objections to the use of a wavelength between 1 and 2 metres unfortunately are too great at present to warrant attention. Indeed, before any serious attention can be given to the possibility of using wavelengths of this order, a very great deal of pioneering research will have to be carried out with a view to the determination of field strengths, etc. There are also grounds for thinking that our present ideas on receiver technique will have to be very drastically revised before such a project could be contemplated.

On the basis of known facts, therefore, the wavelength finally selected for the inauguration of the television service was about the best choice possible, and although, from the ordinary listeners' point of view, it is not without its disadvantages, at least it has a certain definite service value.

After all, we are still only on the threshold of a very far-reaching development, and we cannot hope for finality in the early stages.

But whatever the future may hold in store, from the facts which have been advanced in this chapter, the improbability of television ever being on anything but ultra-short waves will be apparent. Even so, it would be a far too sweeping statement to as much as hint that we have reached finality.

Chapter 18

TELEVISION RADIO SETS

THE PROBLEMS INVOLVED—THE EYE AND THE EAR COMPARED — "SOUND" RECEPTION CONSIDERATIONS — AVOIDANCE OF LOSSES—SURFACE CURRENT-FLOW—THE IDEAL COIL—IMPORTANCE OF RIGIDITY—CONCERNING I.F. TRANSFORMERS—THE DESIRED RESPONSE CURVE —COMMERCIAL EXAMPLES—CONSTRUCTIONAL PRECAUTIONS —CONDENSER THAT BECOMES AN INDUCTANCE—QUESTION OF COST—THE BEST VISION RECEIVER—FREQUENCY-CHANGING ADVANTAGE—THE FINAL CHOICE—AERIAL EFFICIENCY—DIPOLE DETAILS—MOST SUITABLE LOCATION.

From a superficial examination of the problems connected with the reception of high-definition television programmes, there is little doubt that this latest development in the sphere of home entertainment has brought about a greater upheaval in design technique than any other in the history of broadcasting.

There is a two-fold reason for that. In the first case there is the question of linear amplification over a very wide range of frequencies to contend with, and secondly, and mainly because of this enormously wide frequency band, there are the numerous reception problems to be considered due to the use of ultra-short waves.

The Problems Involved. It is not proposed in this present chapter to explain at length the reasons for the wide frequency reception range and for the necessity of using ultra-short waves, for these matters are adequately dealt with elsewhere in this book. But in order to be able to approach the subject of suitable receivers for the new conditions with some idea of the problems involved, it will be as well first to define the requirements of such a set.

Dealing first with the question of vision reception, the essential requirement of this side of the installation is that it shall be capable of giving appreciably linear amplification of a band of frequencies up to $1\frac{1}{2}$ or even 2 megacycles. That means to say that from the aerial input right through the chain of receiving valves to the anode circuit of the output valve, it is necessary in practically every detail to abandon all existing ideas and to tackle the problem entirely afresh. Coils, valves, intervalve-couplings, in fact, almost every individual component must come under the eagle eye of the designer if the ideal of linear amplification of such a wide band of frequencies is to be attained.

BAND-SPREADING SCHEMES

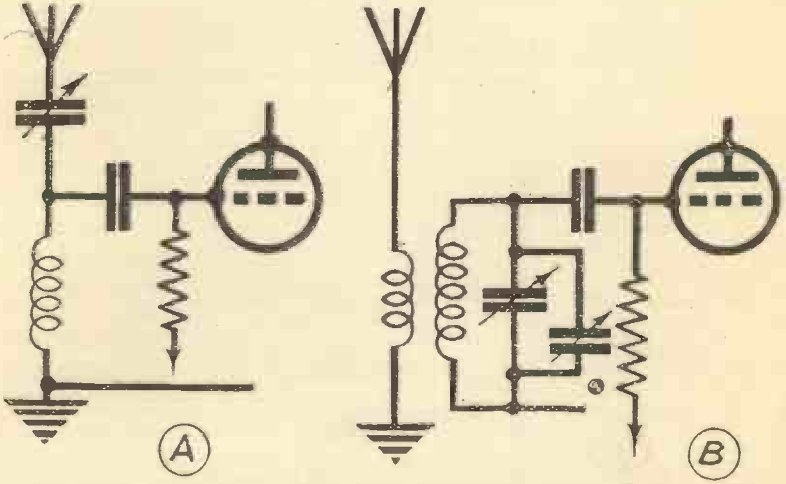


Fig. 153—To simplify operation on ultra-short waves, the use of a band-spreading device is often a great advantage. Circuit "A" shows how band-spreading can be carried out by using a series tuned arrangement, while "B" shows the method of doing it with a tiny parallel condenser

The Eye and the Ear Compared. And it is of the utmost importance that so far as is possible it should be obtained. The average human eye is a far more efficient organ than the ear, and whereas the ear will put up with a certain amount of distortion, and, indeed, due to its comparative inefficiency, may even fail to detect the distortion, the same is certainly not true of the eye.

The slightest flaw, the slightest imperfection or absence of detail in an image before the eye is instantly discernible, and the failure of any one of the numerous components in the vision receiver to deal adequately with the wide range of frequencies which are necessary for the reception of television pictures will, in consequence, completely upset things. With the eye it is a question of perfection or nothing ; with the ear—well, the average listener is not seriously perturbed if a few top notes are missing and probably wouldn't even be aware of it.

To the subject of ensuring that received pictures shall not be imperfect we will return at a later stage of this chapter. But in the meantime, what of the sound side?

" Sound " Reception Considerations. Were it not for the fact that ultra-short waves are also to be used for the transmission of the television sound effects, there would be no difference between television sound reception and the reception of any ordinary broadcast station on the medium waveband, in fact, even as things are, no alterations or departures from convention are called for in that part of the set from the detector onwards.

IMPORTANCE OF LAYOUT

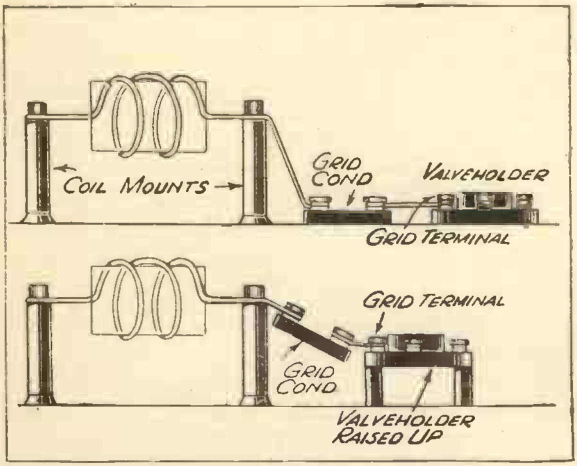


Fig. 154—Layout is of vital importance in the design of an ultra-short wave receiver. These two diagrams show the right (lower sketch) and the wrong way of arranging the grid circuit components

But, of course, the fact that ultra-short waves are to be used does call for special precautions in the design of that part of the set preceding the detector, and so far as general considerations are concerned, what applies in this respect to the vision receiver applies also to that for sound. As has been previously explained, the essential difference between the two is in the matter of the range of frequencies to be received. But the general design problems associated with ultra-short wave reception apply equally to both, and in the consideration which follows of the component question in so far as the pre-detector stages are concerned, the observations can be taken as applying to both.

Avoidance of Losses. Apart from the question of linear response in the case of the vision receiver, what is perhaps the next greatest problem in the design of television receivers—a problem due entirely to the fact that ultra-short waves are involved—is the avoidance of losses. The wavelengths selected for the inauguration of the television service—6.6 and 7.2 metres—are of such enormously high frequency that many factors connected with losses in components which on ordinary broadcast waves could be ignored must now be carefully attended to, and this, in most cases, means new components altogether.

In the case of coils for the reception of these waves, for instance, it is necessary to go very carefully indeed into the question of resistance, self-capacity and external field if maximum efficiency is to be obtained. Unlike the broadcast waves where the frequencies concerned are so very much lower, one has to contend with the possibility of the external field of the coil being far more extensive, and the fact that any metal screening introduced into that field is likely to introduce losses of a most serious kind.

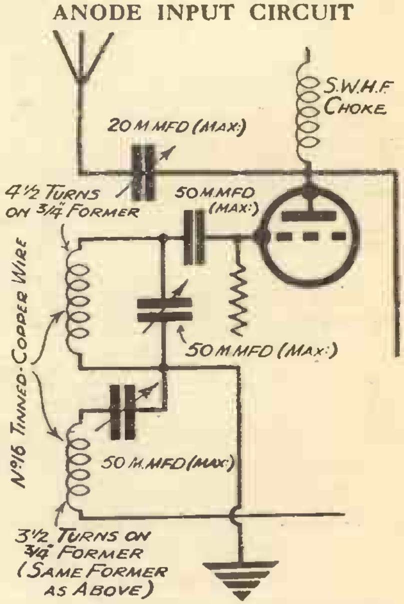


Fig. 155—An advantage may sometimes be gained in the design of a set for the higher frequencies by feeding the aerial into the anode circuit

Surface Current-Flow. Then, too, it has been established that these ultra-high frequency currents flow almost entirely over the surface of the wire used for the inductance, and in consequence the gauge of wire and the nature of its surface are factors which assume tremendous importance, whereas on ordinary broadcast waves there is very wide latitude without any appreciable difference in efficiency, although there is an ideal to be aimed at even in this case.

One other factor which must enter prominently into any discussion on ultra-short wave coil design is that of the avoidance of self-capacity so far as is possible, an effect which unfortunately becomes more pronounced, unless proper precautions are taken, through the use of heavier gauge wire.

From these brief considerations of the pitfalls to be avoided, it will be apparent that the ideal type of coil for these ultra-high frequencies should have as small an external field as possible, and should be of low H.F. resistance and low self-capacity.

While it must be admitted that there is still much work to be done in connection with the design of ultra-short wave coils generally, we have progressed sufficiently far to be able to arrive at a design of coil which falls in reasonably well with the essential requirements.

The Ideal Coil. From research which has already been carried out, it would seem that the most practical way of keeping the external field of the coil reasonably small is by using a coil of small physical size. As for the question of surface area and conductivity, next to silver ordinary copper wire is about the most satisfactory type of wire when its surface is quite clean, and the way to ensure not only that it is clean but that it stays clean is to use enamelled copper wire.

OBTAINING COIL RIGIDITY

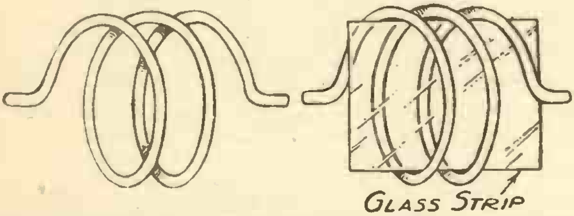


Fig. 156—In the design of ultra-short wave coils, one of the best ways of obtaining rigidity without introducing dielectric losses is to use a strip of glass—preferably Pyrex—as shown

Concerning surface area, or in other words, the gauge of wire most suitable, there are practical limitations to be taken into account, but in general 14 or 16 gauge, while not too unwieldy in use, should be entirely satisfactory.

But a coil made from wire of this type must be widely spaced if self-capacity is to be kept down to a minimum, and the spacing should under no circumstances be less than approximately four times the thickness of the wire used.

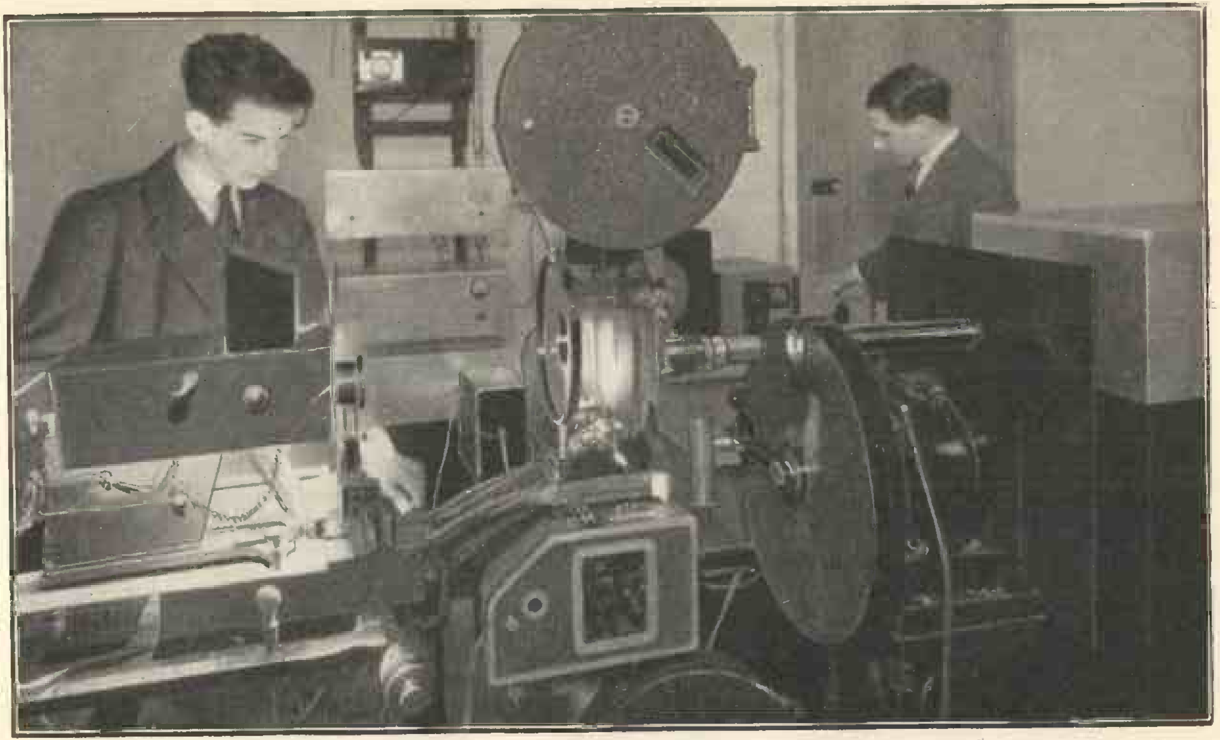
Importance of Rigidity. While, from the point of view of efficiency, the ideal coil for ultra-short wave work is one wound without a former of any description, the advantages gained are likely to be completely offset unless the turns are absolutely rigid. Any movement of the turns in relation to one another will act like a tiny variable condenser across the coil and may completely upset calibration. If, therefore, to obviate the possibility of shifting turns, a former is used, it should, for preference, be of the ribbed variety, and it must in any case be made from an insulator of the highest possible efficiency. Better still, if some satisfactory way can be evolved for anchoring the ends of the wire, a strip of glass—preferably Pyrex—used as a "former" as shown in Fig. 156 would introduce negligible losses.

FOUR DEGREES OF DEFINITION

STANDARD FILM IS TRANSMITTED BY THE GERMAN BROADCASTING STATIONS FOR THE BENEFIT OF EXPERIMENTERS AND OTHERS DESIROUS OF ADJUSTING RECEIVING APPARATUS. ABOVE IT IS SEEN AS TRANSMITTED AND RECEIVED IN FOUR DIFFERENT DEGREES OF DEFINITION, VARYING FROM 30-LINE ON THE EXTREME RIGHT TO APPROXIMATELY 180-LINE ON THE EXTREME LEFT

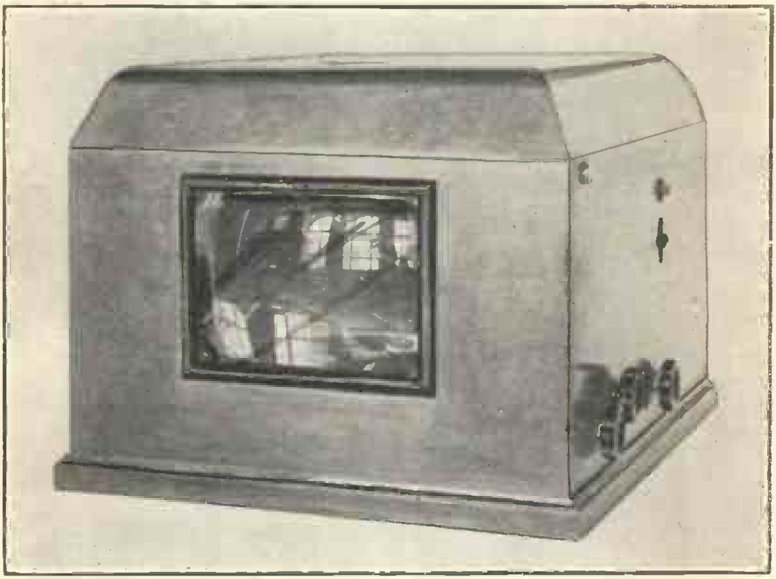
Plate 43

Plate 44

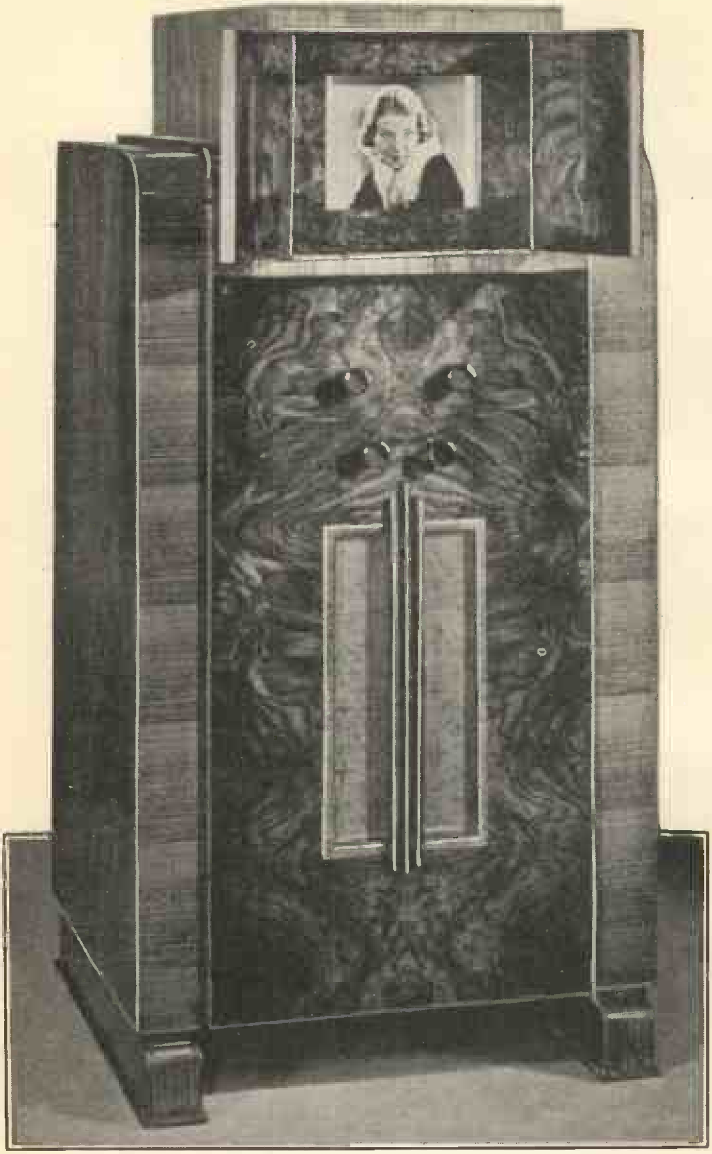


ONE OF THE LATEST BAIRD TELECINE DISC SCANNERS FOR TELEVISING TALKIE FILMS

A GERMAN MECHANICAL VIEWER



THIS NEAT AND COMPACT INSTRUMENT IS A GERMAN MECHANICAL VIEWER USING A SPECIAL MODIFICATION OF THE NIPKOW DISC PRINCIPLE. BUT IT IS NOT SUITABLE FOR THE RECEPTION OF THE VERY HIGH-DEFINITION TRANSMISSION AS IS BEING EMPLOYED FOR THE B.B.C. TELEVISION SERVICE



THE COMPLETE HIGH-DEFINITION, ULTRA-SHORT WAVE TELEVISION RECEIVER MARKETED BY THE GERMAN PHILIPS CO.

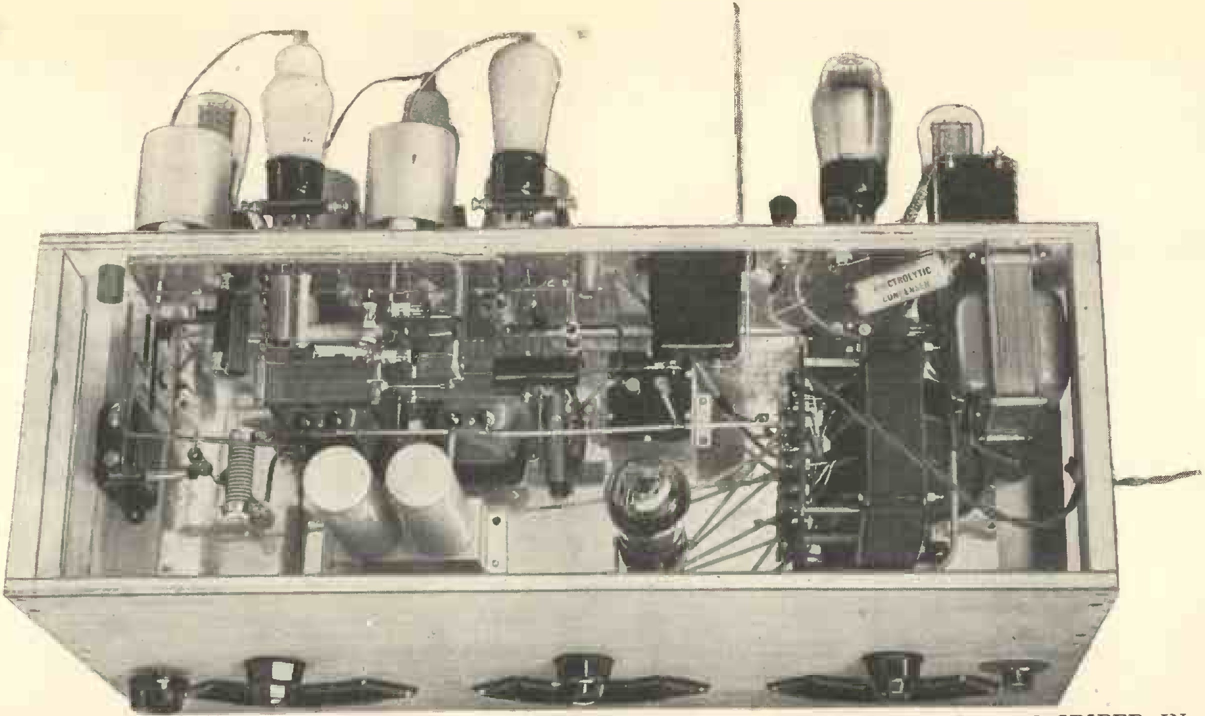
Plate 46

A MODERN CATHODE-RAY TUBE

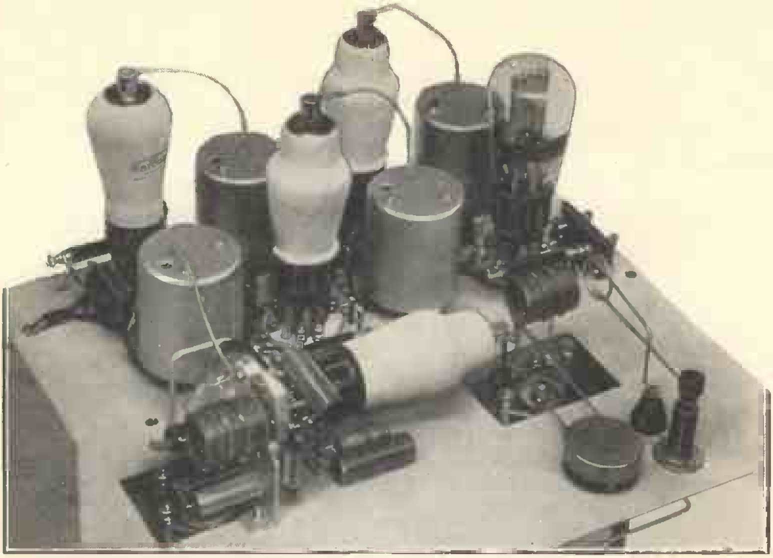
A LARGE CATHODE-RAY TUBE ON WHICH IT IS POSSIBLE TO OBTAIN PICTURES OF ONE HUNDRED SQUARE INCHES IN AREA

Plate 47

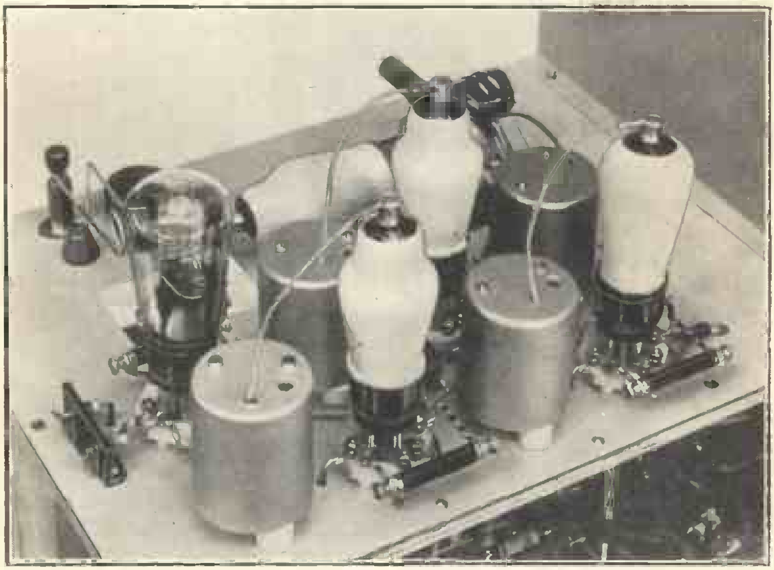
Plate 48



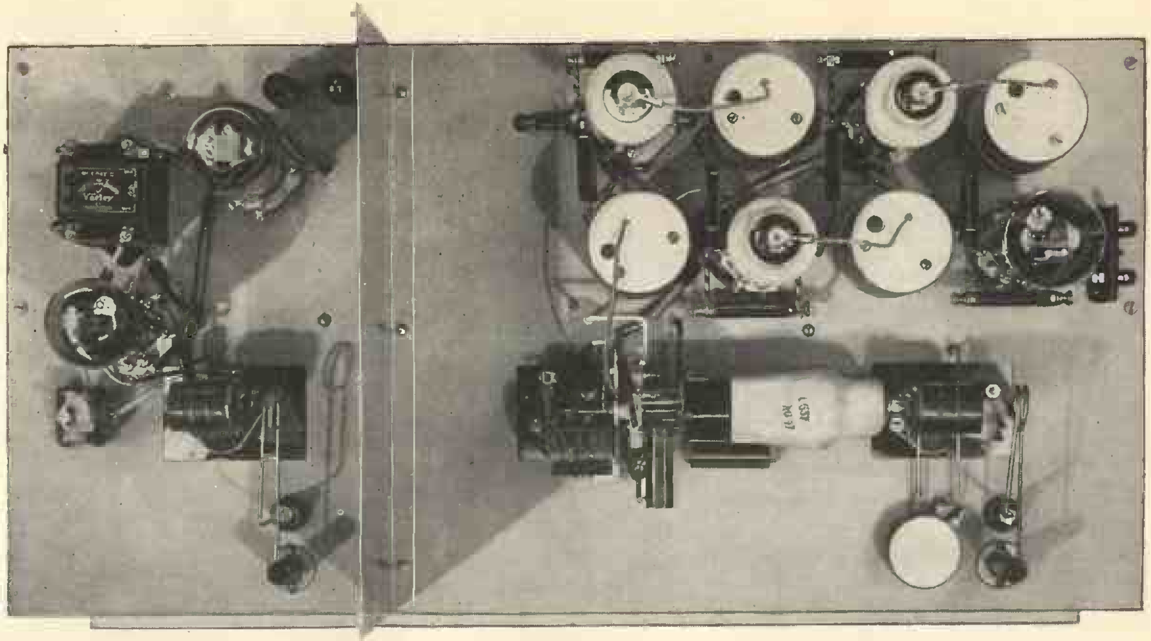
THIS UNDERSIDE VIEW OF THE COMBINED SOUND AND VISION RECEIVER DESCRIBED IN CHAPTER 19 SHOWS THE WAY IN WHICH THE POWER PACK AND SMOOTHING EQUIPMENT IS EFFECTIVELY ISOLATED FROM THE RECEIVING SECTIONS



THIS CLOSE-UP VIEW OF THE SUPERHET SECTION IS TAKEN LOOKING DOWN FROM THE TOP. NOTE PARTICULARLY THE WAY IN WHICH THE METAL " BASEBOARD " IS CUT AWAY TO ALLOW FOR THE PROTRUSION OF THE CONDENSER END-PLATES



IN THIS VIEW OF THE VISION SECTION, THE WAY IN WHICH THE I.F. UNITS ARE RAISED UP FROM THE METAL BY MEANS OF SMALL CHINA INSULATING WASHERS IS CLEARLY SHOWN



EXTREME PRECAUTIONS HAVE BEEN TAKEN IN THE DESIGN OF THIS INSTRUMENT TO AVOID LONG LEADS—A FACT WHICH IS STRIKINGLY APPARENT IN THIS DEAD-ON VIEW OF THE ACTUAL RECEIVING SECTIONS (CHAPTER 19)

In considering the most satisfactory type of tuning condenser for television receivers, the question resolves itself perhaps more into one of mechanics than anything else, for upon the mechanical construction depends to a large extent the ultimate efficiency.

AN ADAPTOR FOR "SOUND"

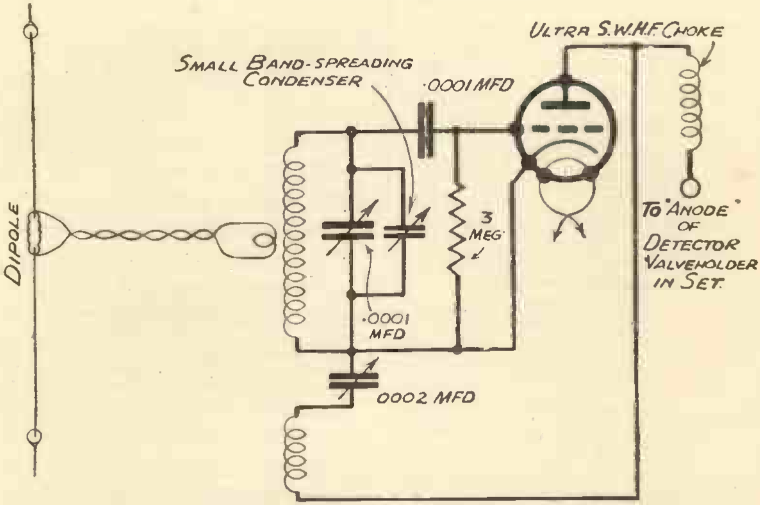


Fig. 157—The most economical way of providing for the reception of television sound programmes is to build an adaptor such as this for use with an existing broadcast set

Here again, the avoidance of loss is of the utmost importance, and the amount of insulating material used in the construction must be kept down to an absolute minimum. Moreover, the insulating material itself must be very high grade. It is also desirable for whatever insulating material that is used to be kept as far as possible out of the electrostatic field of the actual plates.

It is imperative, of course, that the condenser should be of the air-dielectric type, and brass, because it is not so prone to oxidisation as aluminium, is probably the best material for the plates. But even with brass, it is imperative that elaborate precautions should be taken in the assembly to avoid any possibility of noisiness, and it is perhaps fortunate that most of the manufacturers have already had occasion to get to grips with this problem in connection with the design of ordinary short wave condensers.

Concerning I.F. Transformers. As has been previously indicated, this all-important question of the avoidance of losses extends to practically all of the components used, and while it is not proposed to outline the requirements in every single case (the manufacturers have already gone carefully into the question of, and have in fact actually made,—and made well,—such things as valveholders, H.F. chokes, slow-motion drives, etc.), it is of importance that some mention should be made of I.F. coils before passing on to a more general discussion of set designs.

Here it should be made clear that a superhet can hardly be considered necessary for the sound side, for the nature of these ultra-short waves and their propagation characteristics are such as to limit the area over which they can be heard to something like a radius of twenty-five miles from the transmitting station, and, unlike the vision side, since reaction can be introduced into the sound side without disastrous results, a superhet would hardly seem to be called for.

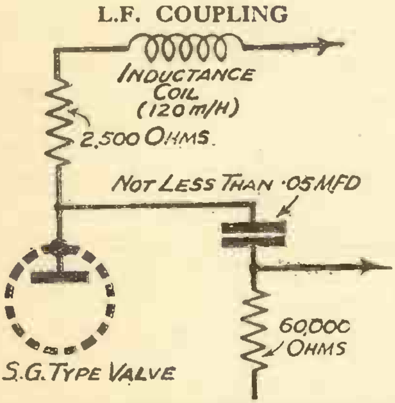


Fig. 158—The use of an inductance in series with the anode resistance in an L.F. stage ensures linear amplification over a much wider range of frequencies than is otherwise possible. It may be found an advantage to experiment with higher-value resistances for the grid leak

The Desired Response Curve. But where, in the case of the vision side, the gain per stage is likely to be low due to the very wide range of frequencies that have to be dealt with, a superhet, or its nearest equivalent in a straight set, would appear to be almost indispensable. And that means to say that in the design of intermediate frequency units for such a set, it is imperative that they should pass a band of frequencies anything up to 1½ or 2 megacycles in width, and that the response curve, to obtain linear amplification, should be appreciably flat-topped throughout this range.

Even now a considerable amount of controversy exists as to the way in which this can best be accomplished, and although much can be done to settle the matter by laboratory experiment, not until the new television service has been in operation for some months can finality be hoped for. The probability is that ultra-short wave I.F. transformers will ultimately be wound with special types of resistance wire although it is too premature as yet to arrive at any definite conclusions in this respect.

Commercial Examples. Whatever may happen eventually, it must in fairness be said that the manufacturers have certainly not been idle, and the units which have already been produced by Bulgin, Eddystone, and Colvern may be found after months of practical experience of the new transmissions to be entirely satisfactory as they stand. From the writer's practical experience of these three makes of I.F. units, it must be admitted that results so far are extremely promising.

Ignoring for the moment the question of wiring and layout, some idea will, it is hoped, have been obtained from the foregoing considerations of the important components—the coils, the condensers, and, in the case of a superhet, the I.F. units—of the extent to which it is necessary to go to avoid losses and to ensure, in the case of the vision receiver, that the band width is received in its entirety.

We can properly leave any consideration of the low frequency side in so far as the vision receiver is concerned until after we have discussed the question of types of sets most suitable for television reception, for in certain cases it is doubtful whether L.F. amplification will be necessary.

Constructional Precautions. But before leaving for the moment this all-important question of the avoidance of losses, it is perhaps desirable just to touch briefly upon some of the constructional precautions which must be taken when making the set or sets, for more havoc can be caused by bad layout and scrappy wiring than by, in some cases, inefficient components.

Bearing in mind the high frequencies with which the set will have to deal, it is of the utmost importance to remember that even a short wire used for connecting purposes is likely to have quite an appreciable inductance. Thus although every endeavour should be made throughout to keep all leads as short as possible, however short they may be it is still desirable properly to space them and, indeed in some cases, even to screen them.

The rigidity of the wiring, too, is also a point of considerable importance, for any tendency for it to spring may have dire consequences upon results. That is why it is advantageous to use stiff wire, for by proper spacing it becomes an easy matter to eliminate as far as possible stray capacities.

No less important is the question of component layout, and unless you have had experience of ultra-short wave receiver technique hitherto, you would be wise not to attempt the construction of a set other than from a published description. Even then, it is vitally important rigidly to adhere to the exact component specification, for remember, that you are dealing with something very different from an ordinary broadcast set.

Condenser That Becomes an Inductance. Just to give an instance of the pitfalls into which the potential builder can stumble by departing from a published description, it is only necessary to consider the case of de-coupling condensers. On ordinary broadcast waves, the capacity of the de-coupling condensers within certain wide limits is not critical, and if a ·01–mfd condenser is specified and you use instead a .1-mfd. it is not likely to make the slightest difference to results.

But if, on ultra-short waves, a condenser of, say, .0002-mfd. is used for de-coupling purposes in a published design, and you happen to have a .1-mfd. paper condenser by you, to use it may completely upset the working of the set, for at the frequencies which are to be received it may become an inductance!

From this example, which is but one of many that could be quoted, it will be apparent that every single component is of importance when it comes to the design of ultra-short wave receivers, and to ensure perfect reception, it is not desirable to take liberties with anything.

Question of Cost. In turning, now, to the types of sets most suited to television, the paramount factor to be borne in mind next to that of efficiency is that of cost. The cathode-ray equipment comprising the tube, time base and power pack is in

SUCCESSFUL FREQUENCY-CHANGER

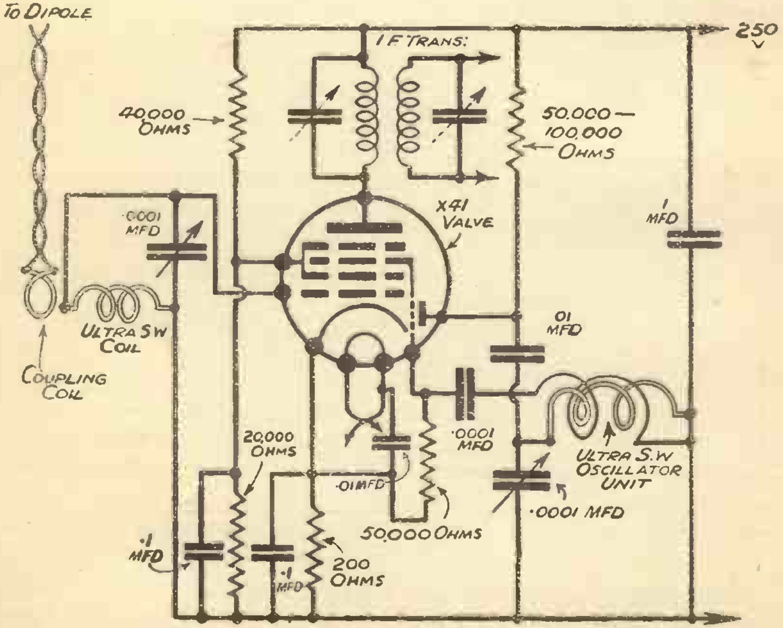


Fig. 159—Marconi and Osram have developed a special type of frequency-changer —the X. 41—for use on ultra-short waves. This circuit shows how best to use it

A DISTORTIONLESS VISION RECEIVER

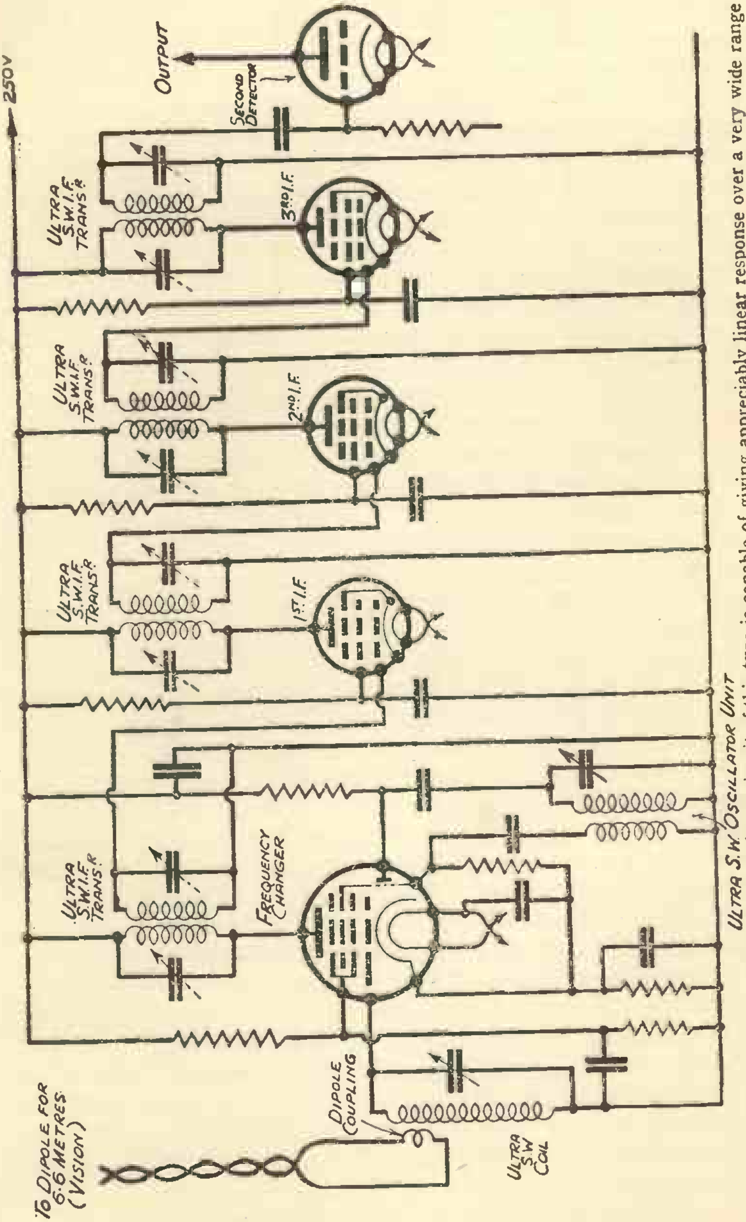


Fig. 160—With properly designed I.F. units, a circuit of this type is capable of giving appreciably linear response over a very wide range of frequencies. The output to the time base should contain a short wave H.F. filter to eliminate the intermediate frequency

itself an expensive item, and since the set is only, in a sense, a means to an end, it is obvious that most listeners will look for the most economical way of building it.

The first question that arises is that of whether the sound and vision can be received on one set. Actually, it can, but it is extremely doubtful whether, at the present stage of development, there is any advantage to be gained. The fact that the two transmissions are separated by only .6 of a metre, and that the side bands of one of them are likely to extend to 1½ or even 2 megacycles introduces difficulties which can only be overcome by circuital elaborations, and it is probably cheaper and certainly much more straightforward to use two completely separate sets.

But since cost must enter into it, what is perhaps the most satisfactory way of all of overcoming the two-set objection is to build a special set for the vision side, and then to use an ultra-short wave adaptor in conjunction with your existing broadcast set for the sound transmission. An adaptor for this purpose is quite an inexpensive proposition, so that the only real cost is in the vision receiver. A circuit for such an adaptor is shown in Fig. 157 and if built having regard to the constructional precautions dealt with previously, it will be completely satisfactory.

That is undoubtedly the most economical way of receiving the sound side, but the next thing to be considered is the most suitable type of set for the vision transmission.

The Best Vision Receiver. Although it is admittedly possible to obtain excellent results with a multi-valve straight set, present tendencies seem to indicate that the superhet type of set is the one that will ultimately be adopted. While it is perhaps true to say of a superhet that initial adjustment difficulties are greater, it is in general far more simple in operation, and because the frequency in the I.F. amplifying chain is of a much lower order than the fundamental station frequency, the actual gain per stage is likely to be higher than is possible with any type of straight set.

If, therefore, because of this increased amplification, the number of valves required can be reduced, cost, likewise, will also be less. For this reason as well as for reasons of simplicity of operation, it may therefore be assumed that the superhet is the most suitable type of set for vision reception.

Later on, when the various valve manufacturers produce—as they undoubtedly will—valves with very low inter-electrode capacities, it is likely that the straight type of set will come back into its own, for the extreme sensitivity of a superhet should not then be necessary for a station, the service area of which is limited to 25 miles. But that is likely to be some time ahead.

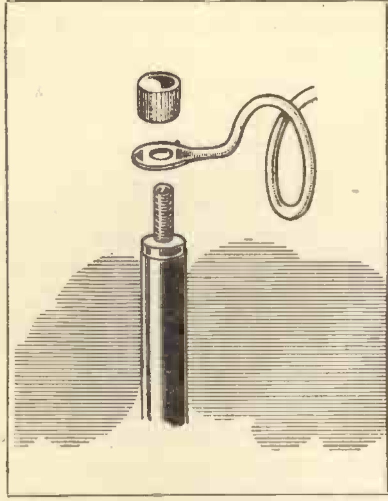


Fig. 161—To ensure sound electrical connection between coil ends and terminals, it is a good scheme to hammer out flat the end of the wire and to drill it as shown here.

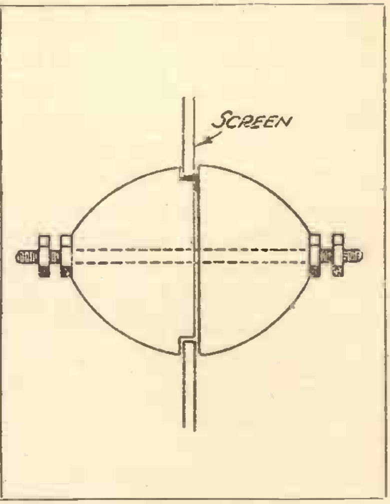


Fig. 162—The avoidance of losses in wires which pass through screens is best achieved by using an insulated connector of the type shown above. These are available from Belling & Lee

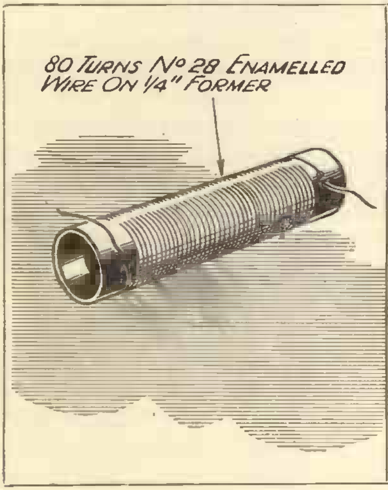


Fig. 163—H.F. chokes for ultra-short waves are very easy to make. The details can be obtained from this diagram, but it is important to use a former of high insulation resistance in order not to introduce losses

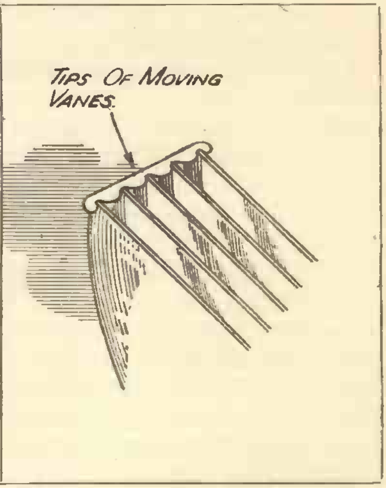


Fig. 164—The mechanical construction of variable condensers for use on ultra-short waves is a point that should be very carefully watched. The moving vanes should be welded together either on the spindle or at the tips

Frequency-Changing Advantage. For the time being we can work only with available apparatus, and since, with existing types of valves, the performance is better when the frequency to be received is lower, the superhet is the only type of set that will enable us to change the very high frequency of an ultra-short wave television station into a lower frequency for purposes of amplification.

As a matter of fact, there is another reason why the superhet would appear to be the best type of set to use. In the case of a straight set, to attempt to use more than two valves in front of the detector is most undesirable because, apart from anything else, of the extreme difficulty of operation. And with only two valves preceding the detector, it may be assumed that some form of L.F. amplification would be indispensable.

Bearing in mind that such an L.F. amplifier would have to be capable of giving linear amplification from 25 cycles to perhaps 2 megacycles, as against 50 to 10,000 cycles in the case of an ordinary broadcast set, some idea of the difficulties involved will be appreciated.

But where, in the case of a superhet, it is possible to have as many as four valves in front of the second detector without in any way complicating operation, it is problematical whether L.F. amplification would be required, for the output from the second detector would be sufficient to operate the cathode-ray tube.

The Final Choice. After careful consideration of the various types of sets that could be used for vision reception, the writer is of opinion that at the present state of development the most satisfactory solution lies in the use of a superhet comprising first detector and oscillator, three intermediate frequency amplifiers, and second detector, and it is this basic circuit—a typical example of which is shown in Fig. 160—which has been selected for the vision receiver which is described in detail in another part of this book.

It is to this chapter that the reader seeking practical information is referred, for when dealing with such colossal frequencies as are employed for television, a circuit diagram alone cannot be considered of much help. The secret of success undoubtedly lies in the components and in the method of construction rather more than in the circuit—a fact that will be strikingly evident when it is realised that to lengthen a grid lead by as little as an inch may make a half-a-metre difference to the wavelength coverage.

But because of the inherent difficulties of relatively low stage gain and high loss potentialities, the secret of successful television receiver design resolves itself into one of taking extreme precautions in every essential respect and in seeking so to overcome the problems as to get to the maximum efficiency possible out of every single component and valve.

Aerial Efficiency. It is of the highest importance, too, to use an aerial designed with the same object in view, and in this connection, because of its superiority over other schemes, there is little doubt that the dipole will come into prominence.

Having regard to the importance of aerial pick-up arrangements it is felt that this chapter on television receivers would be incomplete without just a brief explanation of the dipole and of the way in which it should be erected.

ERECTING A DIPOLE AERIAL

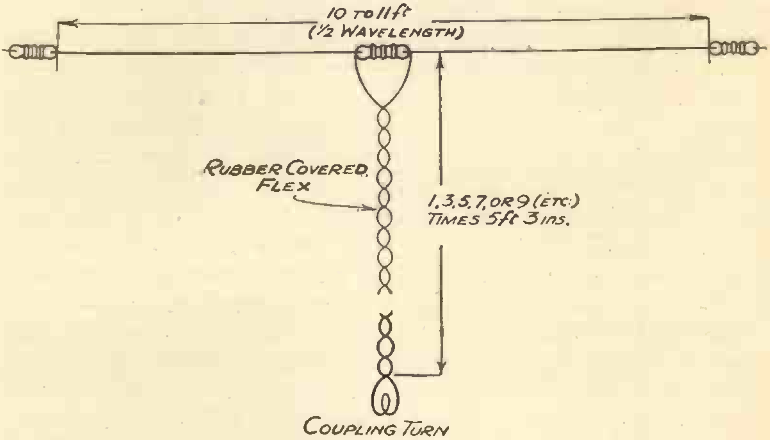


Fig. 165—All the necessary dimensions for the erection of a dipole aerial are shown in this diagram. The length of the downlead must be an odd multiple of 5 ft. 3 ins.

The essential features of a dipole aerial are shown in Fig. 165. It will be seen from this diagram that there are two horizontal spans so arranged that the total length of the horizontal portion is approximately half of the wavelength it is desired to receive. For instance, with the vision programme radiated on a wavelength of 6.6 metres, which is near enough to 21 feet, the overall length of the horizontal span—which must be in two halves insulated from one another at the centre—should be about 10 ft. 6 in.

Dipole Details. Unlike aerials of the orthodox type, the feeders from this aerial or, if you like, the leads-in, are of considerable importance, and for optimum results, their lengths should be arranged in odd multiples of quarter wavelength. In other words, one, three, five, seven, and so on, times approximately 5 ft. 3 ins.

The feeders are taken from the ends of the two horizontal spans which come together at the insulator in the centre, and the ends of the feeders remote from the aerial are connected one to each side of a one-turn coupling coil in the set itself.

As may well be imagined, good insulation is of vital importance, and the insulators both at the ends and in the centre should be the best obtainable.

The wire for the horizontal spans is not critical so long as it is copper and of fairly heavy gauge, and from preliminary experiments, it would appear to be difficult to better the ordinary 7/22's stranded aerial wire. For the feeders, a fairly heavy gauge of twisted rubber-covered flex will answer quite satisfactorily unless man-made static interference happens to be particularly bad in which case it may be necessary to use a system of cross-over feeders. This scheme is shown in Fig. 166. But for all normal purposes, the flex should be good enough.

INTERFERENCE ELIMINATION

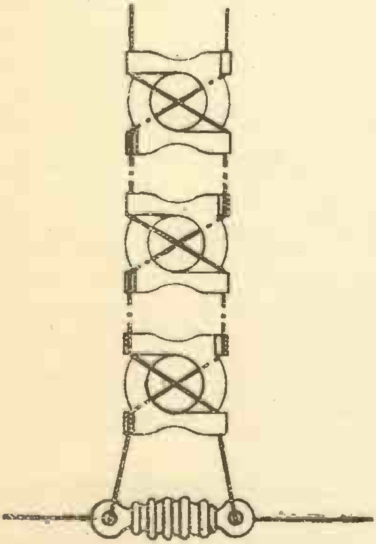


Fig. 166—In cases where man-made static interference is bad, it may be found advantageous to use a system of cross-over insulators for the dipole downleads

Most Suitable Location. As for the height above ground bearing in mind the fact that these television waves are assumed to be more or less "optical" waves, the importance of elevating the aerial as high as possible above buildings, metal roofs, etc., will be appreciated. In normal domestic surroundings it is probable that on the top of the house roof raised up on poles will be the most convenient location, although where possible it may be found an advantage from the point of view of signal strength to arrange the two horizontal spans vertically, with the two feeders coming in through the window.

In this case, the aerial must, of course, be kept well away from the wall, and it can only be done where the level of electrical interference is low, for the vertical aerial will in most cases increase the noise-to-signal ratio.

G. T. K.

Chapter 19

CONSTRUCTING A COMPLETE TELEVISION OUTFIT

AN ORIGINAL CHASSIS SCHEME—MAKING THE FRAMEWORK—MOUNTING THE COMPONENTS—THE RECEIVING SECTIONS—HINTS ABOUT THE WIRING—TIME BASE AND POWER PACK—SPECIAL CHASSIS—HIGH VOLTAGE METER—TESTING THE PACK—TRANSFORMER CONNECTIONS—THE TIME BASE — THE COMPONENT PARTS — FILAMENT FEEDS.

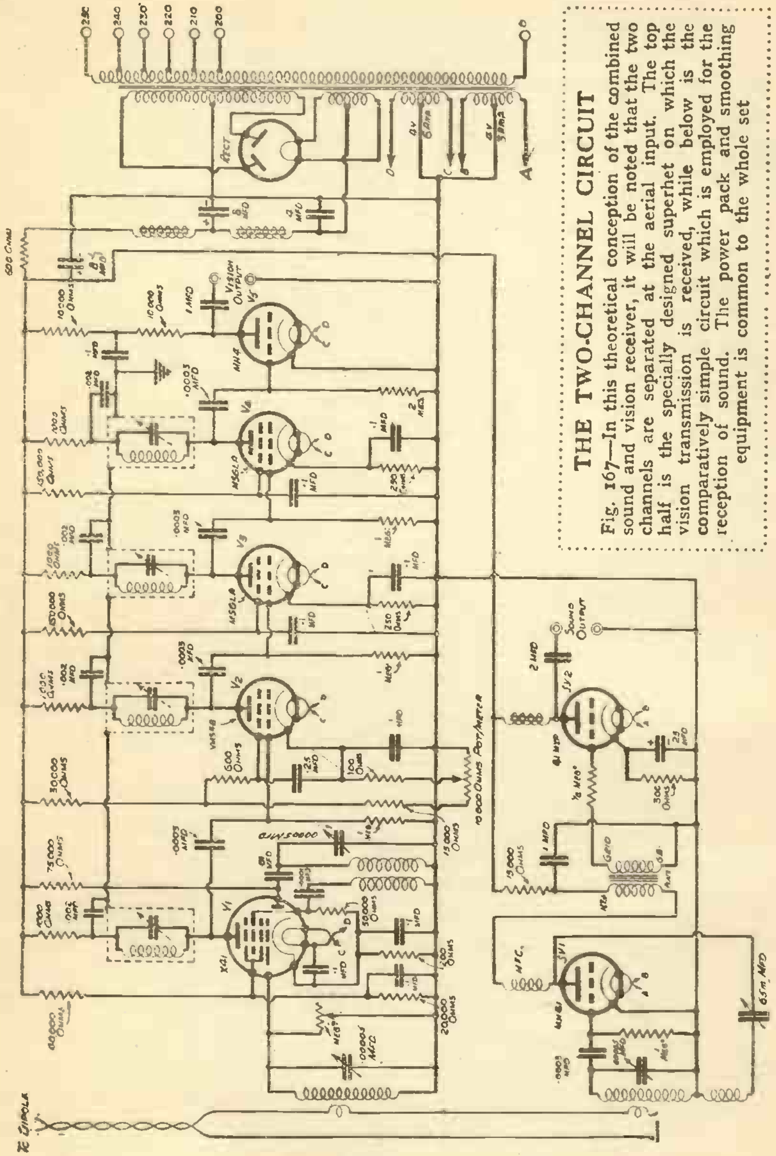
First of all, the set itself. The method of construction employed in this part of the equipment is entirely unique in that no design has ever before appeared that is in any way comparable with it.

It may be divided into four sections. First there is the panel control, extension and condenser section. Then there are the sound and vision receiving chains, and finally there is the power pack, which includes practically all of the voltage dropping resistances and associated by-pass condensers.

Making the Framework. The wooden framework is not difficult to construct, and should be undertaken in the manner to be described in a few moments. But the metal work is rather more involved, and intending constructors are advised to obtain this cut to size and, in the case of the larger vertical metal sheet, with the variable condenser openings pierced, from Messrs. Burne Jones and Co., Ltd.

The wooden framework consists in all of seven pieces, and these are the front panel, the horizontal baseboard, the vertical back-piece and four cross supports. The panel is 24 ins. by 13 ins., the horizontal baseboard is 24 ins. by 7¾ ins., and the back-piece is 24 ins. by 6½ ins. The material is 3-8 ply.

When the panel has been drilled and cut in accordance with the dimensioned photograph provided, this framework can be assembled. Absolute rigidity is obtained by the use of the four



THE TWO-CHANNEL CIRCUIT

Fig. 167—In this theoretical conception of the combined sound and vision receiver, it will be noted that the two channels are separated at the aerial input. The top half is the specially designed superhet on which the vision transmission is received, while below is the comparatively simple circuit which is employed for the reception of sound. The power pack and smoothing equipment is common to the whole set

cross supports, the positions of which will be obvious from the photographs.

With this framework assembled, the next part of the construction should consist of " lining " the three-sided box into which the power pack is built (Fig. 168). The lining consists of a piece of metal (tinned iron) bent to shape and fixed in position with small nails.

It is rather important that this three-sided box should be all in one piece unless, if three pieces are used, the sides which meet are joined together electrically.

To simplify as far as possible the constructional procedure, it will now be best to continue with the assembly of the power pack before mounting in position the variable condensers and the slow motion dials, etc. It is not possible, of course, at this stage to mount all of the components which are built into the power pack because so many of the resistances are actually held in position by the wiring.

MAINS TRANSFORMER KEY

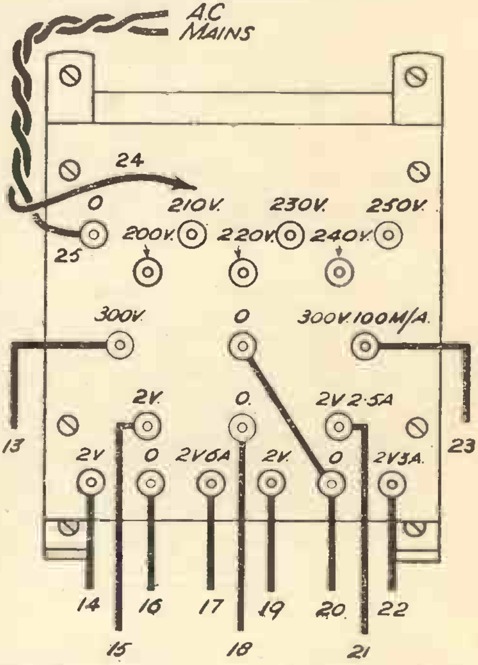


Fig. 169—This key to the connections on the mains transformer should be used in conjunction with the wiring diagram shown in Fig. 168

Mounting the Components. But you can go ahead and mount all of the components which are held down by screws such as the mains transformer, the L.F. chokes, smoothing condensers, etc. Having done that, leave this part of the construction for the time being, and continue with the variable condensers and dials. The actual positions of the three variable condensers will, of course, be determined by the dials on the panel with which they must line up, but with regard to the distance of these components from the panel, they should be arranged so that the terminals are just flush with the edge of the holes in the vertical metal sheet through which they project.

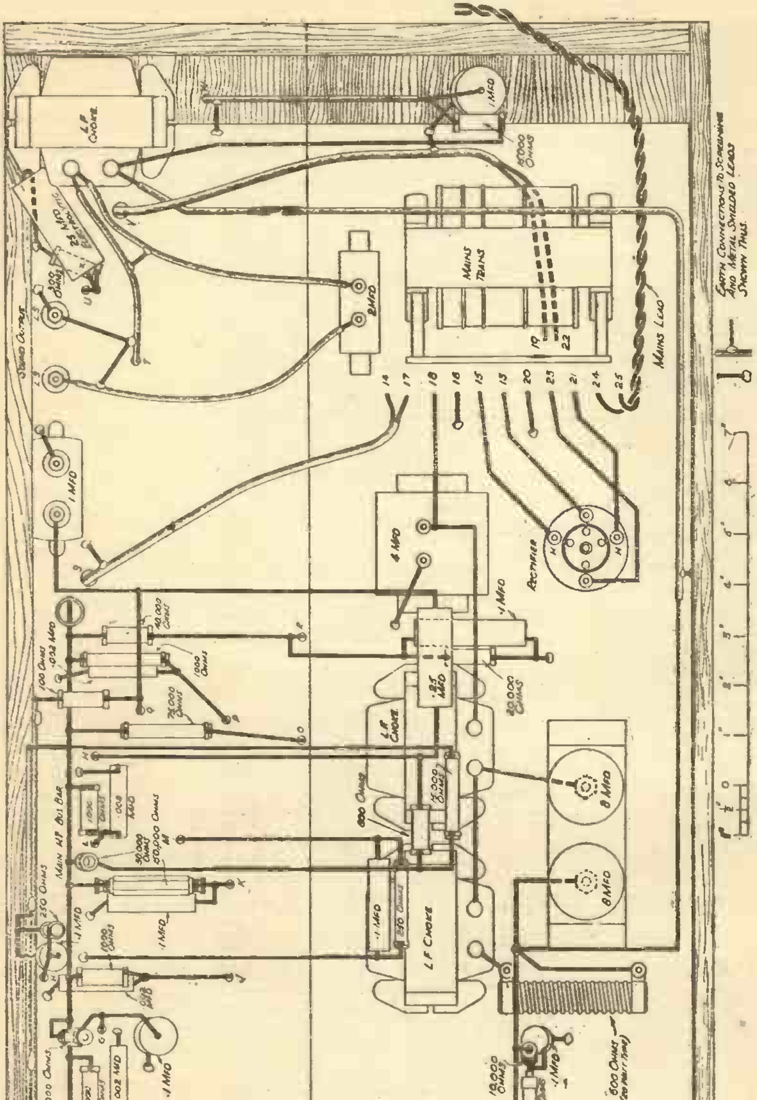


Fig. 168—The method of lining the underside of the chassis will be clear from this drawing. For convenience when wiring up, a length of stiff tinned copper wire, supported at each end by an insulating pillar, is used as a main H.T. busbar

This vertical metal sheet, by the way, should not yet be in position, and the condenser positions should be determined simply by holding it in place.

The fitting of the extension rods and the flexi-coupling junctions is straightforward enough, and although a certain amount of inaccuracy in lining up the variable condensers with the slow-motion drives can be taken up in the flexi-couplings, it is better to try to aim at dead accuracy.

With regard to the reaction condenser, there are one or two points which should be carefully watched when this is being

THE SOUND DETECTOR CIRCUIT DETAILS

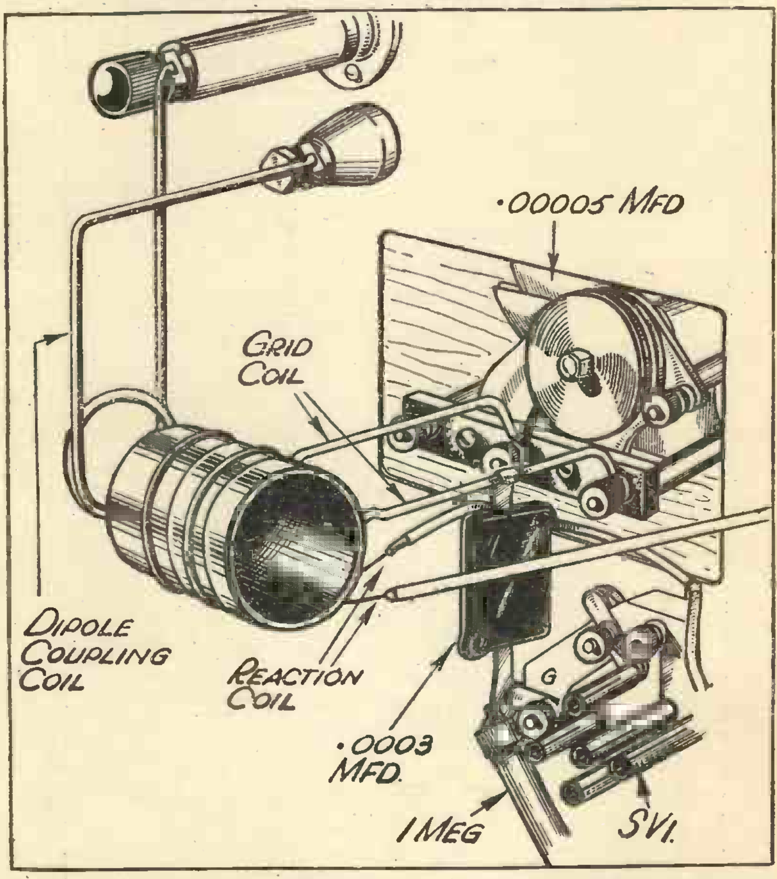


Fig. 170—The method of mounting the various components associated with the grid circuit of the first valve in the sound receiver is clearly shown in this sketch. It also shows how the dipole coupling coil, which consists of a single turn, should be made and mounted

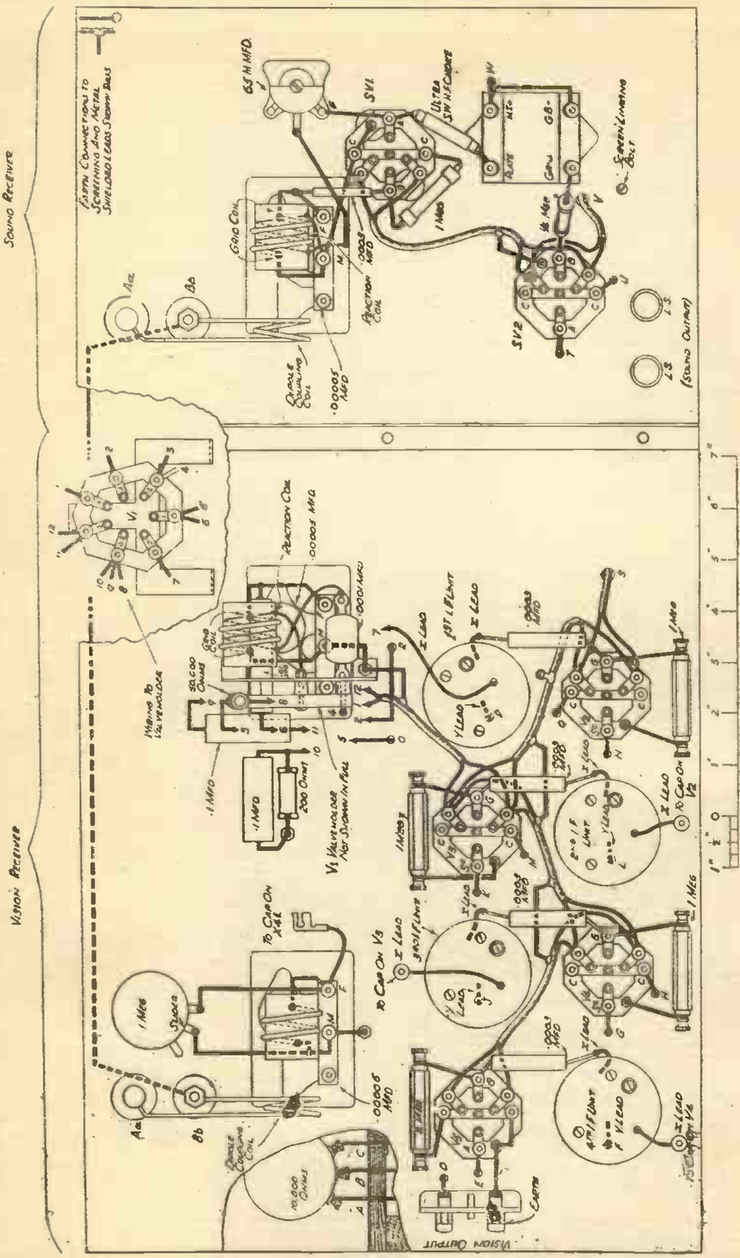


Fig. 171—For convenience in assembly, certain of the components which are fixed to this vertical metal "baseboard" should be mounted before the metal sheet is secured to the main wooden chassis. This point is dealt with in the text

mounted. In the first case, the slow motion head which is fitted to the panel is only made for use with ¼-inch panels, and since the front panel in this case is thicker, it will be necessary to drill away some of the wood at the back. One further point. The spindle of the actual condenser is unfortunately too small in diameter for the collar of the extension handle, but this difficulty can easily and effectively be overcome by packing the spindle out with copper foil.

The Receiving Sections. Now with regard to the actual receiving sections.

Again to simplify as far as possible the constructional procedure, certain of the components are fixed to this metal "baseboard" before it is fixed in position. That does away with the necessity of passing bolts right through the wooden support to which the metal is ultimately secured, but apart from that, there is another important reason—a reason, incidentally, which rules out wood-screws.

If you examine the diagram (Fig. 171), you will notice that certain of the component fixing screws are used for earthing points, and by carrying out the assembly in the way suggested, good contact is ensured.

The components which should be fixed to the metal sheet before this latter is secured in position are the valveholders (including the X41 valveholders which is mounted on a metal bracket) and the intermediate frequency units. The heads of the fixing bolts must, of course, be counter-sunk at the back so that the metal sheet can be fixed flush against the wood.

There are two points in connection with this part of the construction to which attention should be called. First with regard to the I.F. units. You will notice that there are two leads coming out of the bottom and one—a flexible lead—out of the top. This flexible lead is common with one of the leads coming out of the bottom, and before mounting each unit you must take off the cap at the bottom and mark the lead that is common. These common leads are all shown as "x" in the wiring diagram, and the other lead of each unit is shown as "y."

The "y" leads have all to go through to the power pack compartment, and therefore before finally mounting the I.F. units the appropriate holes should be drilled. Incidentally, the I.F. units and the "sound" detector valveholder are all raised up from the metal by means of insulating washers roughly half-an-inch thick. These you will no doubt be able to obtain from your local dealers, although the ones in the original set were obtained from one of the wireless stalls in a London market!

COMPONENTS FOR THE SOUND-VISION RADIO SECTION

3	.00005-mfd. variable condensers (J.B. Short-Wave Special type)
3	Slow-motion dials (J.B. dual-ratio "Arcuate" type)
3	Coupling rods, 4 ins. in length (J.B.)
3	Flexi-coupling units (J.B.)
1	65-m.mfd. (maximum) reaction condenser (Eddystone type "Ditri")
1	Panel-mounting slow-motion drive for above (Eddystone type "Driad")
1	6-inch extension spindle (Eddystone type "Atec")
1	Flexi-coupling unit (Eddystone)
1	10,000-ohm volume control (Colvern)
1	6-inch extension spindle for above (Bulgin type E H 2A)
1	bracket for above volume control (B.R.G. No. 22)
1	1-megohm potentiometer (Erie)
1	signal frequency 7-metre coil (Bulgin S.W.60)
2	signal frequency 7-metre coils with reaction (Bulgin S.W.61)
4	Television I.F. units, 50-megacycle type (Bulgin S.W.62)
6	5-pin valveholders (Bulgin "Frequentite" type S.W.21)
1	7-pin valveholder (Bulgin "Frequentite" type S.W.51)
1	4-pin baseboard type valveholder (W.B.)
1	8-mfd. dry-electrolytic condenser (T.C.C. type 902)
1	8-mfd. dry-electrolytic condenser (Dubilier type 0281)
1	4-mfd. Mansbridge type condenser (500-volt working, T.M.C.-Hydra)
1	25-mfd. dry electrolytic condenser (Dubilier type 3001)
1	2-mfd. Mansbridge type condenser 300 volt working (T.M.C.-Hydra)
2	1-mfd. Mansbridge type condensers (Dubilier type B.B.)
1	.25-mfd. tubular fixed condenser (T.C.C. type 350 v.d.c.)
1	1-mfd. tubular fixed condenser, 300 volt working (T.M.C.-Hydra)
1	.1-mfd. tubular fixed condenser, 350 volt working (Ferranti)
4	.002-mfd. fixed condensers (T.M.C.-Hydra type T.12)
2	.1-mfd. tubular fixed condensers (T.C.C. type 250)
1	.1-mfd. tubular fixed condenser (T.M.C.-Hydra type T.24)
4	.1-mfd. tubular fixed condensers (Dubilier 4513)
1	.01-mfd. tubular fixed condenser (T.C.C. type 300)
1	.0001 fixed condenser (Dubilier type 665)
1	.0003 fixed condenser (T.C.C. type M.)
4	.0003 fixed condensers (Dubilier type 670)
1	Ultra S.W. H.F. choke (Eddystone)
1	250,000-ohm 1 watt resistance with wire ends (Formo)
1	1-meg. 1 watt resistance with wire ends (Formo)
3	1-meg. resistances with terminals (Graham-Farish Ohmites)
1	2-meg. resistance with terminals (Graham-Farish Ohmites)
1	200-ohm 1 watt resistance with wire ends (Amplion)
1	50,000-ohm 1 watt resistance with wire ends (Amplion)
1	15,000-ohm 1 watt resistance with wire ends (Amplion)
1	300-ohm 1 watt resistance with wire ends (Amplion)
1	20,000-ohm 1 watt resistance with wire ends (Amplion)
1	40,000-ohm 1 watt resistance with wire ends (Amplion)
1	1,000-ohm 1 watt resistance with wire ends (Erie)
1	75,000-ohm 1 watt resistance with wire ends (Erie)
1	100-ohm 1 watt resistance with wire ends (Amplion)
3	1,000-ohm 1 watt resistances with wire ends (Amplion)
1	600-ohm 1 watt resistance with wire ends (Amplion)
1	15,000-ohm 1 watt resistance with wire ends (Erie)
1	30,000-ohm 1 watt resistance with wire ends (Amplion)
2	250-ohm 1 watt resistances with wire ends (Erie)
2	150,000-ohm resistances with terminals (Graham-Farish Ohmites)
2	10,000-ohm 1 watt resistances with wire ends (Formo)
1	600-ohm 20-watt resistance (Bulgin type P.R.3)
1	Mains transformer (Varley type special)
3	L.F. chokes (Wearite type H.T.12)
1	L.F. transformer (Varley Nicore 2)
	Special metal chassis work in accordance with diagrams (Burne Jones)
1	double electrolytic condenser mounting bracket (Peto Scott)
1	X41 valve holder bracket (see text)
2	terminals engraved "Aerial" and "Earth"—one with insulating bush—(Belling Lee type B)
1	terminal mount (Graham-Farish "Pop" type)
2	low-loss stand-off insulators (Belling Lee No. 1222)
2	low-loss stand-off bushings (Belling Lee No. 1223)
10	stand-off insulating washers (see text)
2	¾-inch pillars (for supporting main H.T. busbar)
	Metalised sleeving, wire, systoflex, screws, nuts, and bolts, flex, etc.
1	wooden panel, 13 ins. by 24 ins. (⅜-in. oak-faced plywood)
1	wooden baseboard, 8 ins. by 24 ins. (⅜ in. plywood)
1	wooden back-piece, 6 ins. by 24 ins. (⅜-in. plywood)
4	wooden cross-supports, 7⅜ ins. long by 1⅞ ins wide, by ⅝ in. thick.

VALVES

1	Marconi MH41	sound receiver
1	Cossor 41MXP	
1	Marconi X41 (ultra-short-wave type)	Vision receiver
1	Marconi VMS4B	
2	Cossor MSG/LA	
1	Marconi MH4	
1	Marconi MU12 rectifier	

You need not worry about mounting the 1-meg volume control, the two pillar terminals marked " Aa " and the two insulated screen connectors marked " Bb " at this stage, although it is best to see that the holes are drilled before the vertical metal " baseboard " is secured in position which, incidentally, should be the next job.

With this firmly secured to the back piece of wood, the remainder of the components, including those just mentioned, can be fixed. Just one further point before approaching the wiring question.

HOW THE X 41 VALVEHOLDER IS MOUNTED

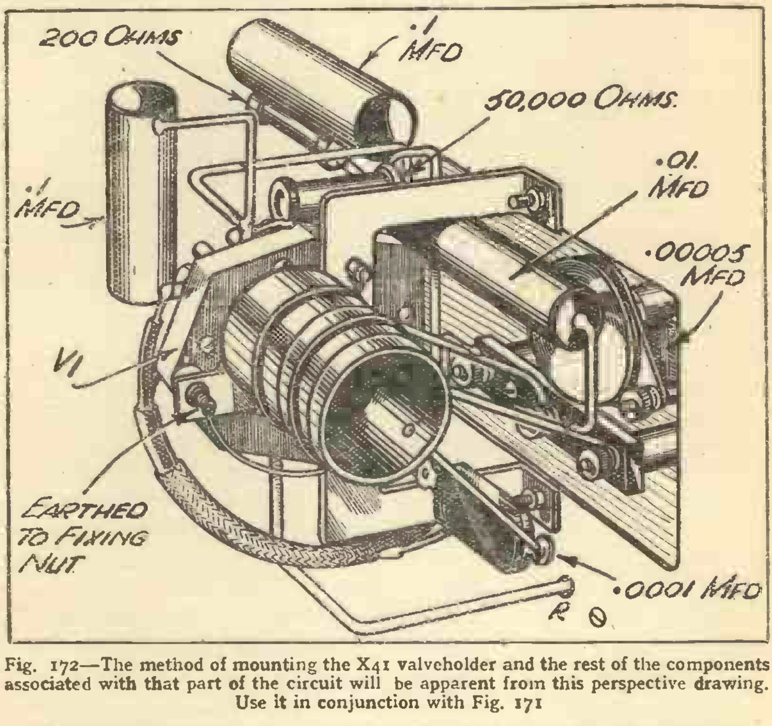


Fig. 172—The method of mounting the X41 valveholder and the rest of the components associated with that part of the circuit will be apparent from this perspective drawing. Use it in conjunction with Fig. 171

The metal bracket on to which the valveholder for the frequency changer is mounted should be cut to shape in accordance with the dimensions which, with the aid of the scale, you will be able to obtain from the wiring diagram. If you do not fancy making this yourself, you will no doubt be able to get it made for you when you order the remainder of the metal work. But it requires to be a fairly strong bracket.

Hints About the Wiring. Not a lot can be said in connection with the wiring for it is so much a question of following it out carefully from the diagrams provided. In every case where a wire passes from one section of the set to another through a hole, the holes are marked with key letters which correspond in each diagram.

You will notice that certain of the wires, particularly in the power pack, are metal shielded. This is done with a view to eliminating mains interference trouble, but the insulation between the actual connecting wire and the metal shielding must be capable of standing up to about 300 volts. It is also vitally important that all leads passing through the metal work should be very carefully insulated from it. The same thing applies to one of the sound receiver output terminals—the one nearest the screen.

When your set is completed and has been carefully checked, you will be able to obtain full details regarding operation from the chapter which deals with this subject. G. T. K.

Time Base and Power Pack. The construction of the time base and the power pack, and the assembly of the whole receiver is not by any means a difficult matter.

You have read how the radio portion of the outfit is made, and with that part completed and carefully checked the rest of the television receiver can be started.

At this point one must consider the accessibility of the whole instrument, and it becomes apparent that it is not the sort of thing that can be assembled on the kitchen table and hooked up more or less anyhow. The various units that go to make it must be readily get-at-able but at the same time they must be logically placed, sufficiently screened from one another and so situated that adjustments can be made without difficulty and with safety.

This latter point is most important. In a receiver of this type we are dealing with voltages of up to 3,600 and they cannot be regarded with impunity. At the same time, though complete screening of the high voltage sections would be ideal from a safety point of view it renders adjustments tedious, and the sections would increase in weight and unwieldiness.

What has been done in the construction of the television receiver illustrated is suggested as a good method of providing reasonable safety and complete accessibility.

Special Chassis. An iron chassis or framework is made with four compartments (Fig. 173). The top one takes the time base and the cathode ray tube. The second one down takes the radio set and its power pack. The third is for the speaker, and the bottom shelf is where the power pack for the time base and tube is placed.

If desired, the whole of the framework, except the panels, can be covered in with sheet iron, rendering the whole thing completely shielded and also absolutely safe to all but the most careless.

We qualify the safety of the apparatus because we want it to be realised that a television set is one that holds definite danger in the way of electric shock to any who is not circumspect in his handling of the set. Provided only the controls are touched during the time when the power is on no harm will result.

But if the intervals of the time base or its power pack are given attention while the power is on a very nasty shock is almost inevitable. Very frightening to read about, no doubt, but forewarned is forearmed, and there is no need to get a shock at all.

FOR HOUSING THE TELEVIEWER

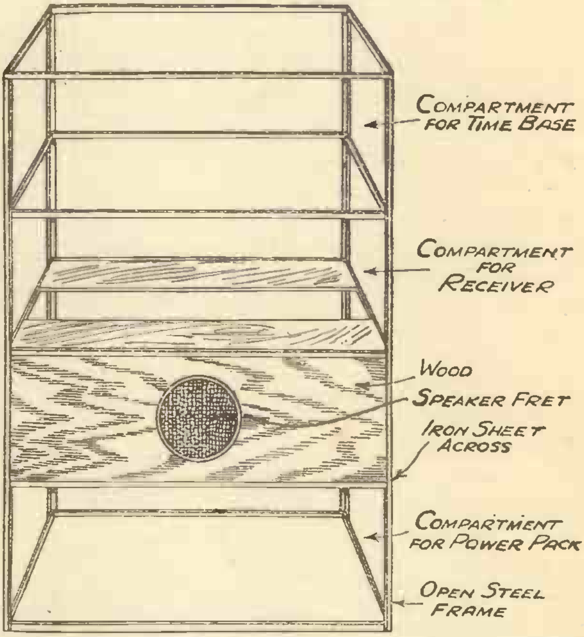


Fig. 173—The metal chassis constructed for holding the television outfit. The chassis goes en bloc into the cabinet after the setting adjustments have been made

Through all the experiments that were made during the designing of this receiver, and many of them were carried out with much more rough and ready hook-ups than the layout shown, no shock of any kind—electrical, that is—was received. This was simply because care was taken that no adjustments except to the proper controls were made without the juice being switched off, and time given for condensers, etc., to discharge through the various resistance paths.

The chassis was chosen because it allows the whole apparatus to be tested out in the form in which it will finally be used, and the whole chassis can be inserted in the cabinet when the tests have proved themselves satisfactory. Incidentally, the wiring of the time base can most conveniently be carried out while the baseboard is *in situ* in the top section of the rack.

High Voltage Meter. It may be mentioned here that one of the most valuable pieces of apparatus when building and testing a television set is a high voltage electrostatic meter. It is not necessary to buy one with a high maximum; one with a full scale deflection of 450 volts is quite convenient. This meter is connected up on a board with terminals and resistances in accordance with Fig. 174 and are connected in series with each other to form the circuits shown.

Various voltage maxima can be obtained from 450 to 3,600. This is most useful, for it enables the power pack voltage outputs to be tested before they are applied to the cathode tube or to the time base. Especially is this desirable in the case of the shield bias, for we must make sure that this is reaching the shield of the tube before the actual tube is placed in circuit.

CHECKING THE VOLTAGES

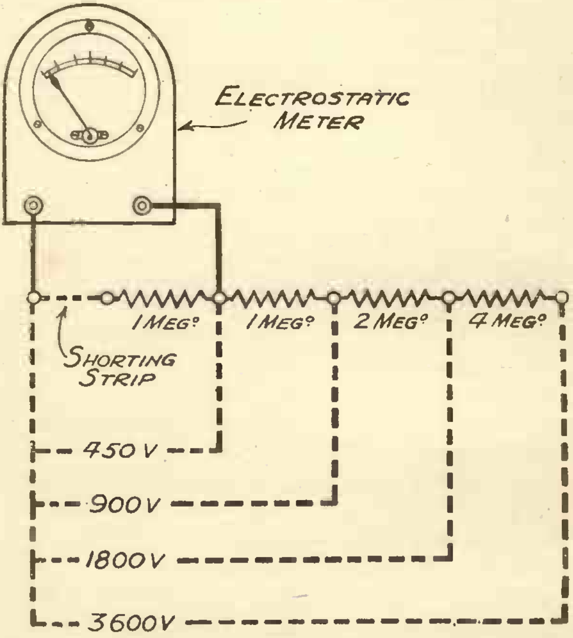


Fig. 174—An electrostatic meter reading up to 450 volts is ideal for television purposes as the voltage readings can be doubled, quadrupled and then again doubled by the use of resistances as shown

Testing the Pack. There is very little in the actual construction of the time base or the power pack, and it is not necessary to discuss the matter in detail. The power pack is best built first and thoroughly tested out with the meter, and also given a " life " or endurance test. This consists in connecting to the mains and leaving on for some quarter of an hour to see if anything heats up.

Nothing should get hot, but if a faulty resistance is in circuit with the potentiometer system on the high voltage side of the power pack it will show up during this test.

This test is carried out with the large rectifying valve (RZI/150)—that for the time base section—pulled out of its socket. We want only to test the part of the pack that is delivering power to the cathode-ray tube.

TELEVISION POWER PACK COMPONENTS.

1 power transformer type 5ST208 (Bryce)
1 power transformer type PW/TV (Savage)
3 1-mfd. fixed condensers type 951 (Dubilier)
6 4-mfd. fixed condensers type 111 (T.C.C.)
1 2-mfd. fixed condenser type 650 v. working (Dubilier)
3 50-henry smoothing chokes type AB100 (Bryce)
1 smoothing choke type L.F.21.S. (Bulgin)
1 2-megohm potentiometer (Reliance)
1 .5-meg. potentiometer (Reliance)
1 .1-meg. potentiometer (Reliance)
1 2-meg. 1-watt resistance (Erie)
1 1-meg. 1-watt resistance (Erie)
1 ½-meg. 1-watt resistance (Erie)
1 12,000 ohms 1-watt resistance (Erie)
2 5-pin Steatite valveholders type S.W.21 (remove C terminals) (Bulgin)
1 valve-holder for RZ1/150 (Mullard)
14 indicating terminals type B (Belling & Lee)
1 ebonite terminal strip 6 in. by 1½ in. by 3-16th in.
1 ebonite terminal strip 11 in. by 2 in. by 3-16th in.
1 ebonite panel 10 in. by 7 in. by 3-16th in.
1 wood baseboard 24 in. by 24 in. by ⅝ in.
18 S.W.G. T.C. wire
Sleeving
3 mm. rubber-covered flex
40/36 twin flex

VALVES.

1 Ediswan M.U.2
1 Ediswan D.L.S.1
1 Mullard RZ1/150

The power pack is built on perfectly straightforward lines (Fig. 175), on a thick baseboard with a small panel to carry the three controls, and terminal strips or blocks for the terminals.

The pack is made so that the panel comes at the right-hand side of the chassis when the power pack is in position, a door on the right of the cabinet allowing access to the controls when the receiver is in position in the cabinet.

Those controls are focusing, shield bias, and main accelerator or gun potential. This latter can be left at maximum or any other point in accordance with the brightness required on the screen. The other two have to be varied when the set is first installed and after that should not need touching.

The circuit of the power pack is shown in Fig. 176, and it will be seen that a safety resistance is connected across the shield bias potentiometer to obviate any danger to the cathode-ray tube should the slider of the potentiometer fail to make contact at any point.

In the wiring of the power pack care must be taken that the wires are well spaced, and no two wires should touch except at junction points. Systoflex sleeving is used but it must not be assumed that this provides complete insulation should the wires

HOW THE DOUBLE POWER PACK FOR THE TIME BASE IS WIRED

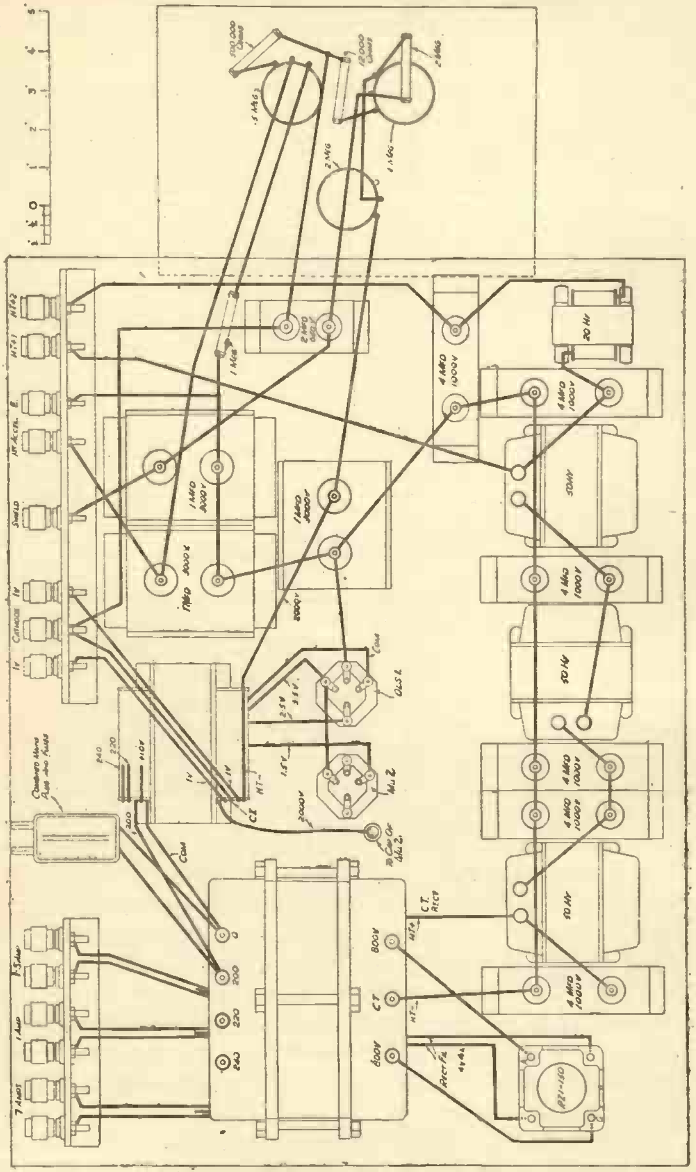


Fig. 175—Every care must be taken in building the power pack that connections are made correctly. The power transformers are supplied with data cards on which the colour of the wires and details of the outputs from the various windings are given

touch, for many of the potentials with which we have to deal are too high for systoflex to prove an insulator.

THE POWER PACK CIRCUIT

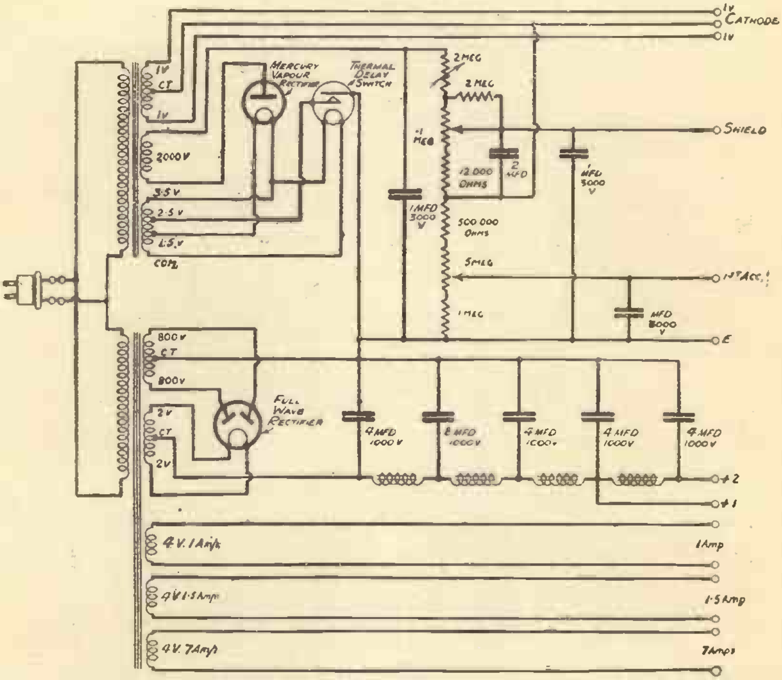


Fig. 176—The various transformer outputs can be seen in this theoretical diagram of the power pack. Note how the tapped winding is used for the mercury vapour rectifier and the thermal delay switch

The power pack for the cathode tube and the pack for the time base are mounted side by side. They link up together only at the earth point, which is connected to the second accelerator or the gun of the tube. This point is connected to actual earth, so that we have two lots of H.T., one with the positive pole earthed and the other with the negative. Therefore the potential between the two negatives is something of the order of 3,600 volts, and this should be borne in mind when the apparatus is being handled.

Transformer Connections. The connections of the power pack are very simple, but care should be taken that the right ones are made, and the leads from the power transformers should be carefully checked. A mistake here may upset things very badly and even cause the loss of valves and perhaps the cathode-ray tube.

HOW THE VALVES ARE ARRANGED IN THE TELEVISION TIME BASE

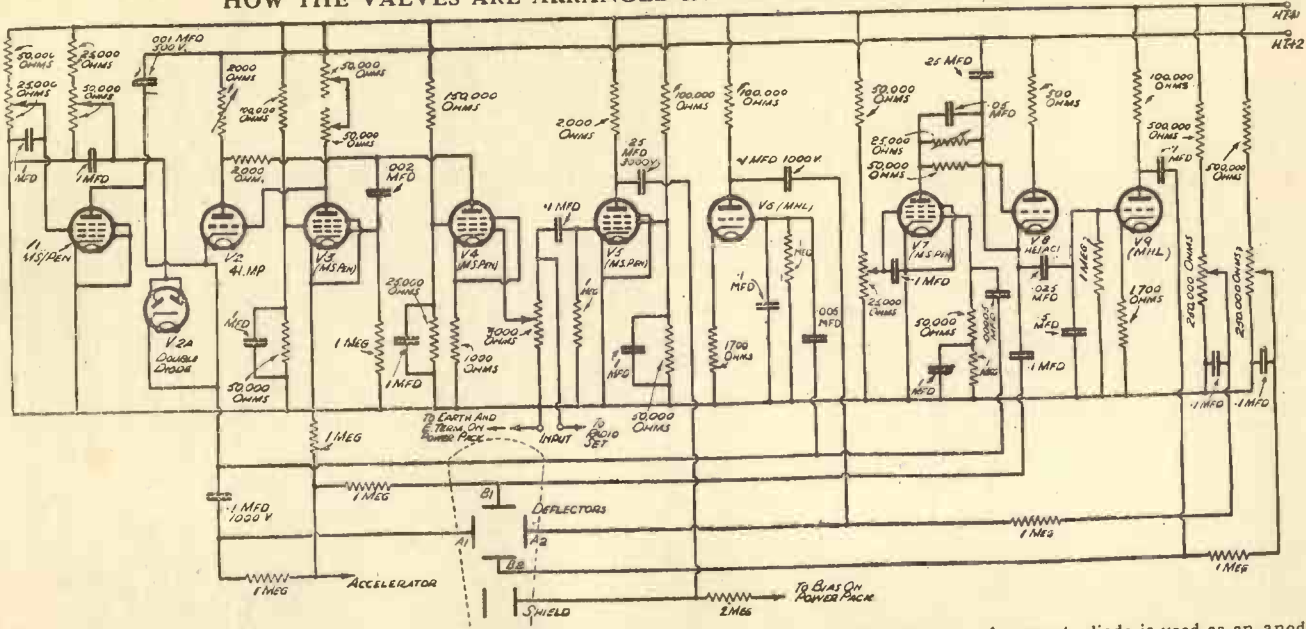


Fig. 177—The theoretical circuit of the time base used in the television viewer described in these pages. A separate diode is used as an anode current control or locking valve for the multi-vibrator circuit

The transformers are supplied with coloured leads from the various windings, and labels showing the meanings of the various colours. The transformers have been specially designed for the power pack we are describing and no others should be used.

All connections that do not go to terminals should be soldered, and everything should be tightened up to ensure security. You cannot afford to have anything coming loose in a power pack of this description.

The Time Base.—The time base section of the receiver is a little more complicated to wire than the power pack, but it is quite easy if it is done carefully and slowly. Fig. 177 shows the theoretical circuit. Do not hurry it. A mistake in wiring may upset the apple cart and will not be at all easy to find. So do every bit carefully, checking over the leads as you go on.

It is best to start with the mounting of the wooden cradle for the cathode-ray tube, Fig. 178, making sure you have it in the right place, and also the support for the tube valve holder, Fig. 179. The orientation of this holder may vary slightly with individual tubes so it should be tested before being finally fixed on the vertical wooden support.

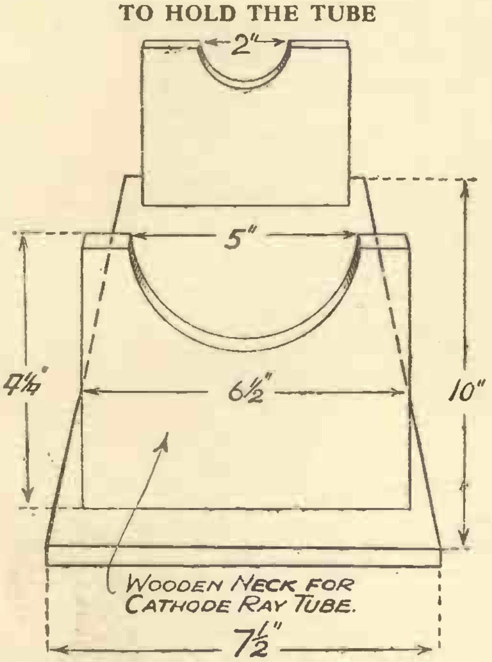
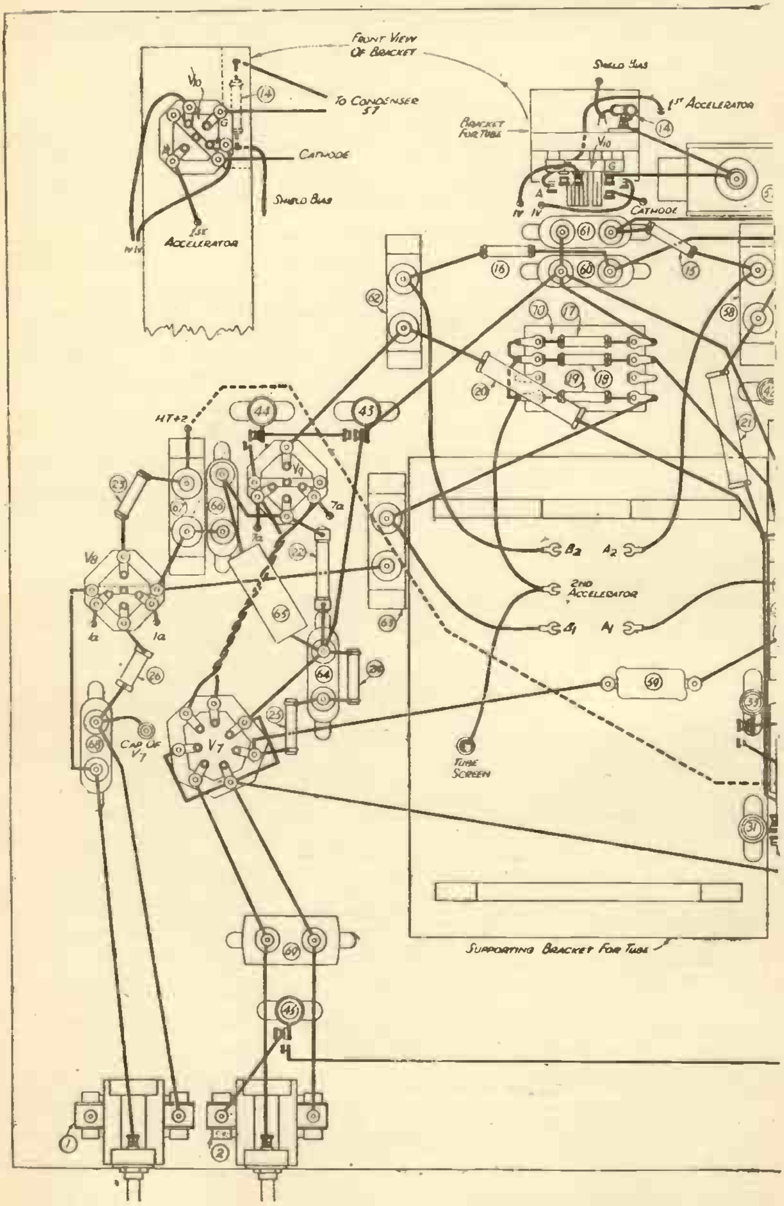


Fig. 178—The cradle for the cathode-ray tube is made to these dimensions if an A H tube is used. If the CH is employed a slightly larger cradle will be required

The valve holder should be so mounted that one pair of deflectors in the tube comes vertical, and the other pair horizontal. We have so set it that the pair nearer the screen of the tube is vertical.

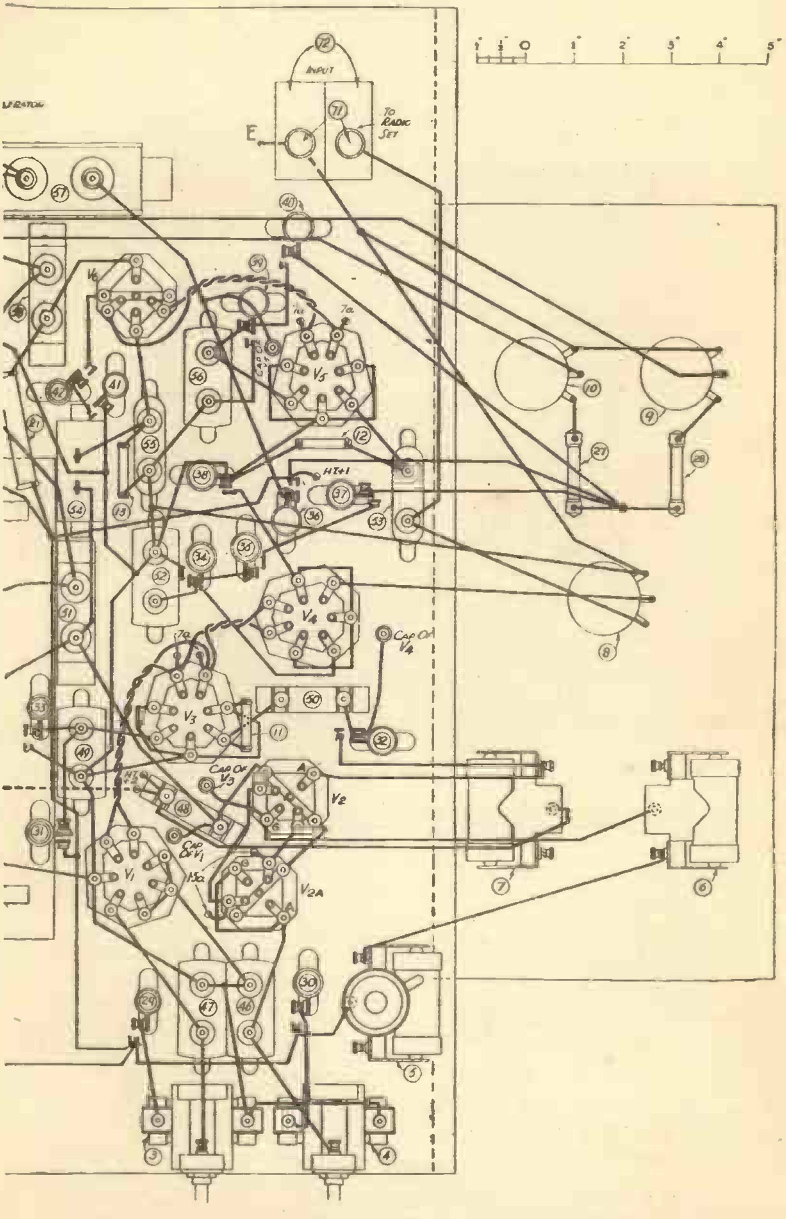
Do not mount all the components on the baseboard before you wire up. It is best to start with either one side or the other of the time base and to mount the parts as required, Figs. 180 and 181.

THE WIRING DIAGRAM OF



Figs. 180 and 181—The wiring diagram has been divided into two parts, but a wide
easily be followed. The numbers against the components are for

THE TELEVISION TIME BASE



overlap has been arranged where the two join so that the individual connections can
the purpose of cross reference with the component list on page 254

THE COMPONENTS NEEDED FOR BUILDING THE TIME BASE.

Key No.	
1	25,000 ohms potentiometer type C.P.64 (Varley)
2	25,000 ohms potentiometer type C.P.64 (Varley)
3	25,000 ohms potentiometer type C.P.64 (Varley)
4	50,000 ohms potentiometer type C.P.66 (Varley)
5	50,000 ohms potentiometer type C.P.66 (Varley)
6	50,000 ohms potentiometer type C.P.66 (Varley)
7	2,000 ohms potentiometer type C.P.153 (Varley)
8	30,000 ohms potentiometer (Polar N.S.F.)
9	¼ meg. potentiometer (Polar N.S.F.)
10	¼ meg. potentiometer (Polar N.S.F.)
11	1 meg. 1 watt resistance (Polar N.S.F.)
12	1 meg. 1 watt resistance (Polar N.S.F.)
13	1 meg. 1 watt resistance (Polar N.S.F.)
14	2 meg. 1 watt resistance (Polar N.S.F.)
15	1 meg. 1 watt resistance (Polar N.S.F.)
16	1 meg. 1 watt resistance (Polar N.S.F.)
17	1 meg. 1 watt resistance (Polar N.S.F.)
18	1 meg. 1 watt resistance (Polar N.S.F.)
19	1 meg. 1 watt resistance (Polar N.S.F.)
20	100,000 ohms 5 watt resistance (Polar N.S.F.)
21	100,000 ohms 5 watt resistance (Polar N.S.F.)
22	1 meg. grid leak heavy duty (Bulgin)
23	500 ohms 1 watt resistance (Polar N.S.F.)
24	1 meg. 1 watt resistance (Polar N.S.F.)
25	50,000 ohms 1 watt resistance (Polar N.S.F.)
26	50,000 ohms 1 watt resistance (Polar N.S.F.)
27	½ meg. heavy duty grid leak (Bulgin)
28	½ meg. heavy duty grid leak (Bulgin)
29	50,000 ohms 20 watt vertical resistance (Bulgin)
30	25,000 ohms 20 watt vertical resistance (Bulgin)
31	100,000 ohms 40 watt vertical resistance (Bulgin)
32	2,000 ohms 20 watt vertical resistance (Bulgin)
33	50,000 ohms 20 watt vertical resistance (Bulgin)
34	25,000 ohms 20 watt vertical resistance (Bulgin)
35	100,000 ohms 40 watt vertical resistance (Bulgin)
36	2,000 ohms 20 watt vertical resistance (Bulgin)
37	50,000 ohms 20 watt vertical resistance (Bulgin)
38	1,000 ohms 20 watt vertical resistance (Bulgin)
39	50,000 ohms 20 watt vertical resistance (Bulgin)
40	100,000 ohms 40 watt vertical resistance (Bulgin)
41	200 ohms 20 watt vertical resistance (Bulgin)
42	1,500 ohms 20 watt vertical resistance (Bulgin)
43	1,500 ohms 20 watt vertical resistance (Bulgin)
44	200 ohms 20 watt vertical resistance (Bulgin)
45	50,000 ohms 20 watt vertical resistance (Bulgin)
46	1 mfd. fixed condenser type B.B. (Dubilier)
47	1 mfd. fixed condenser type B.B. (Dubilier)
48	.001 fixed condenser type 620 (Dubilier)
49	1 mfd. fixed condenser type B.B. (Dubilier)
50	.002 mfd. fixed condenser type 620 (Dubilier)
51	.1 mfd. fixed condenser type 111 (T.C.C.)
52	1 mfd. fixed condenser type B.B. (Dubilier)
53	.1 mfd. fixed condenser type B.B. (Dubilier)
54	.005 mfd. fixed condenser 1,000 v. working (T.M.C.—Hydra)
55	.1 mfd. fixed condenser type B.B. (Dubilier)
56	1 mfd. fixed condenser type B.B. (Dubilier)
57	.25 mfd. fixed condenser type 951 (Dubilier)
58	.1 mfd. fixed condenser type 111 (T.C.C.)
59	.00005 mfd. fixed condenser type 670 (Dubilier)
60	.1 mfd. fixed condenser type B.B. (Dubilier)
61	.1 mfd. fixed condenser type B.B. (Dubilier)
62	.1 mfd. fixed condenser type 111 (T.C.C.)
63	.1 mfd. fixed condenser type 111 (T.C.C)
64	.1 mfd. fixed condenser type B.B. (Dubilier)
65	.5 mfd. tubular fixed condenser 300 v. working (T.M.C.—Hydra)
66	.025 mfd. fixed condenser 1,000 v. D.C. test (Dubilier)
67	.25 mfd. condenser type 111 (T.C.C.)
68	.05 mica condenser 1,000 v. D.C. test (Dubilier)
69	1 mfd. fixed condenser type B.B. (Dubilier)
70	1 resistance board 5-way (see text) (Bulgin)
71	2 indicating terminals type B—(Belling Lee)
72	2 single terminal blocks (Goltone)
	Baseboard 24 in. by 24 in. by ⅜ in. plywood
	Wood (⅜ in. ply) for cathode-ray tube supports
	4 brackets type 23 (Peto Scott)
	1 ebonite panel 18 in. by 7 in. by 3-16th in. (Peto Scott)
	Special chassis frame for set (Burne Jones)
	V1, V3, V4, V5, V7—7-pin Steatite valveholders type S.W.50 (Bulgin)
	V2, V2a, V6, V8, V9, V10—5-pin Steatite valveholders type S.W.21 (Bulgin)
	18 S.W.G. Tinned Copper wire.
	Sleeving for above.
	Screws, etc.

VALVES

V1, V3, V4, V5, V7 ..	Cossor MS/Pen (7-pin)
V2	Cossor 41 M.P.
V2a	Cossor D.D.4
V6, V9	Cossor 41 M.H.L.
V8	Ediswan HE/AC1
V10	Ediswan C.R. Tube type A.H. (I.H.)

NOTE: In the above list of parts the numbers on the left-hand side correspond with the numbers of the components on the wiring diagrams of the time base. They therefore act as keys to the parts used and their types and values.

We commenced with the panel parts and the power potentiometers. Next came the valveholders nearer the front of the baseboard and the wiring to these was done, including the filament wiring, holes being left through the baseboard where required for the connection of the filaments to the leads that come up from the power pack. These leads were fixed last of all.

THE CATHODE-RAY TUBE HOLDER

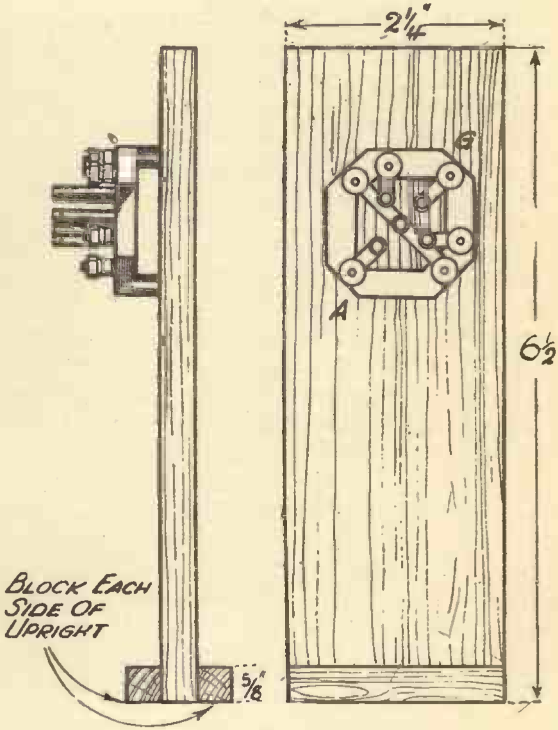


Fig. 179—The valveholder for the cathode-ray tube is mounted on a vertical piece of wood as shown

The perforated shields that are supplied with the potentiometers can be left on if desired. They act as useful protection; but you should refrain from waggling the sliders up and down the resistances more than you can help. It tends to wear them out, and they should never be made to travel fast in any case.

Note exactly how each component is situated with regard to the adjacent ones, and also its orientation. Keep exactly to the lay-out and the positioning, for there is little space to spare and you do not want the leads to have to run haphazard all over the place. Systoflex is again used to cover the bare tinned copper wire, and again we recommend that care be taken that leads do not touch except at junctions.

Work back from the front of the time base on the one side, and then when that has been wired up tackle the other side. We did the right hand side first.

The Component Parts.—You will have to keep rigidly to the parts specified throughout this receiver if you are to duplicate the results. Valve alternatives cannot be used unless you are prepared to spend a long time in adjustment and perhaps alteration of resistance values. In fact, in research.

We strongly advise you not to change the parts in any way whatever, not even in the apparently most simple and every-day component.

The construction of a television receiver is a tricky job from the technical point of view. It is so easy to upset the travel of that lively spot of light, or more correctly the stream of electrons inside the tube, as you will find when you come to adjust the time base for actual scanning.

If you are going to build the set drop a line to the Editor, for television technique is tearing ahead and we may have some further news to give you. Also if later you strike a snag write to us again. Your queries will be forwarded to the proper quarter and we will do our best to assist you. But at the outset let us say that a television receiver is not a thing you can take liberties with like you can in the construction of the average medium and long wave wireless receiver.

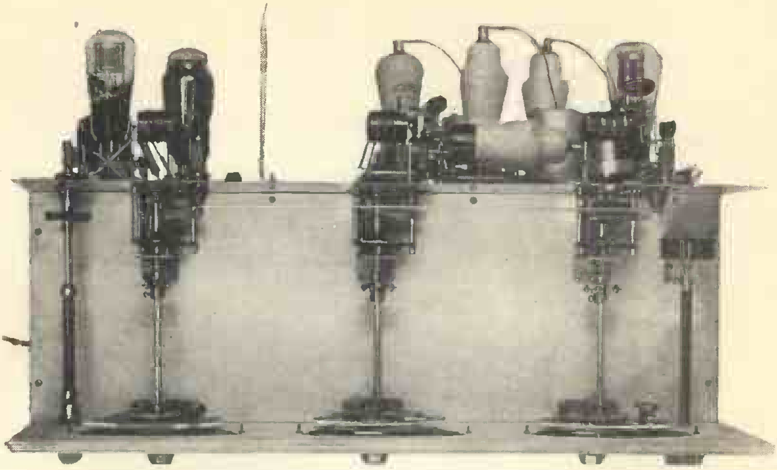
As you will see from the circuit the actual time base arrangement is very similar to that described on page 199—while the power pack is one that has been developed for use with the Ediswan cathode-ray tube. The time base circuit, originated by O. S. Puckle, uses instead of the diode triode, that he suggests in the circuit we gave on page 199, a separate double diode and a power valve. This latter is the famous 41 MP and it carries out its task excellently.

The gas discharge valve used on the " slow " or picture scanning side is an Ediswan helium-filled tube, the HE/AC1 and is particularly constant in its operation.

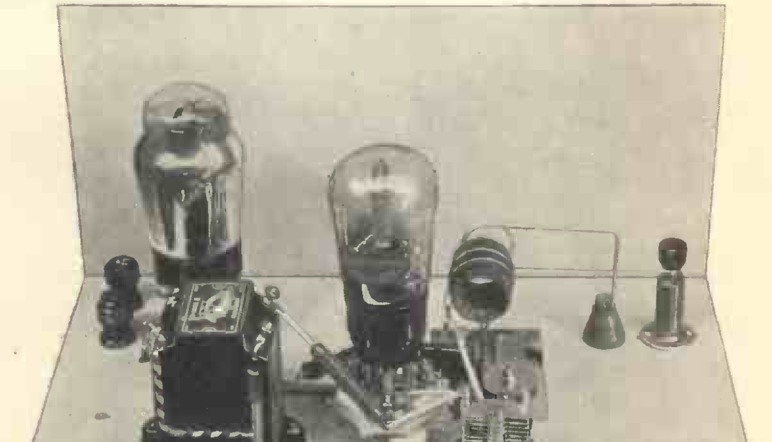
The wiring diagram of the time base has been shown in as clear a fashion as possible. The component values are not marked, so that space is not crowded by a lot of lettering. A key to the components is provided on another page and reference to this in conjunction with the numbering of the parts on the diagrams will enable the whole layout to be pieced together without difficulty.

We obviously could not get the whole wiring diagram on one page of this book, so we have had to split it up, allowing a fair amount of overlap between the sections so that no difficulty in following the wiring at the divisions should be experienced.

Filament Feeds.—Note that the helium discharge valve has a separate filament feed, and so also have the diode and 41 MP

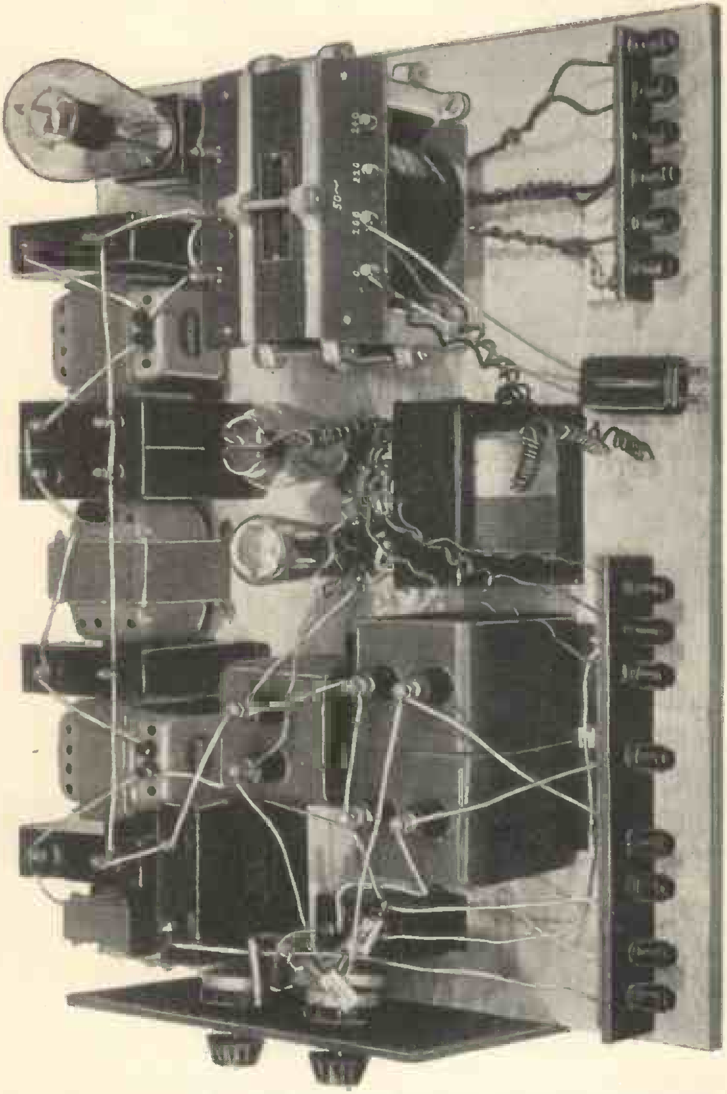


THE WAY IN WHICH EXTENSION HANDLES ARE USED TO ELIMINATE HAND-CAPACITY EFFECTS IS CLEARLY SHOWN IN THIS BIRD'S-EYE VIEW OF THE FINISHED INSTRUMENT. EXTREME PANEL AND CHASSIS RIGIDITY IS OF THE UTMOST IMPORTANCE (SEE CHAPTER 19)



HERE IS A CLOSE-UP VIEW OF THE SOUND SECTION OF THE RECEIVER. BY CAREFUL ARRANGEMENT OF THE COMPONENTS THERE ARE NO WIRES ASSOCIATED WITH THE DETECTOR GRID CIRCUIT WHICH ARE MORE THAN AN INCH OR SO IN LENGTH

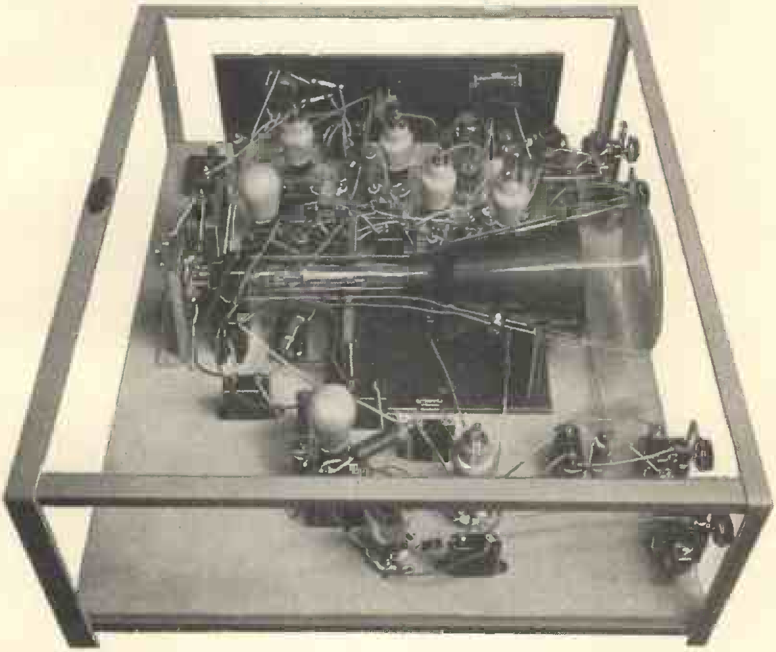
THIS FITS IN THE LOWEST PORTION OF THE CHASSIS



THE GENERAL LAYOUT OF THE POWER PACK CAN BE SEEN HERE. THE RIGHT-HAND GROUP OF TERMINALS ARE FOR THE L.T. SUPPLY TO THE TIME BASE. ALL THE H.T. WIRING SHOULD BE WELL SPACED SO THAT THE HIGH POTENTIALS SHALL NOT STRAIN THE INSULATION AND POSSIBLY CAUSE BREAKDOWN

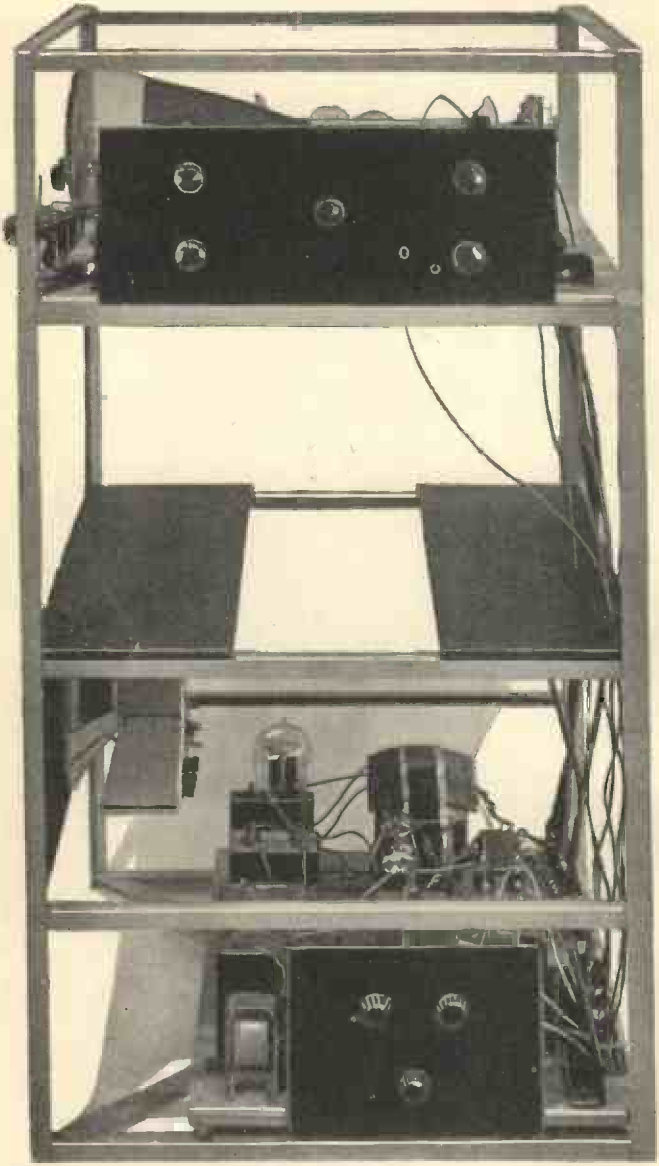
Plate 52

THE HIGH DEFINITION TIME BASE



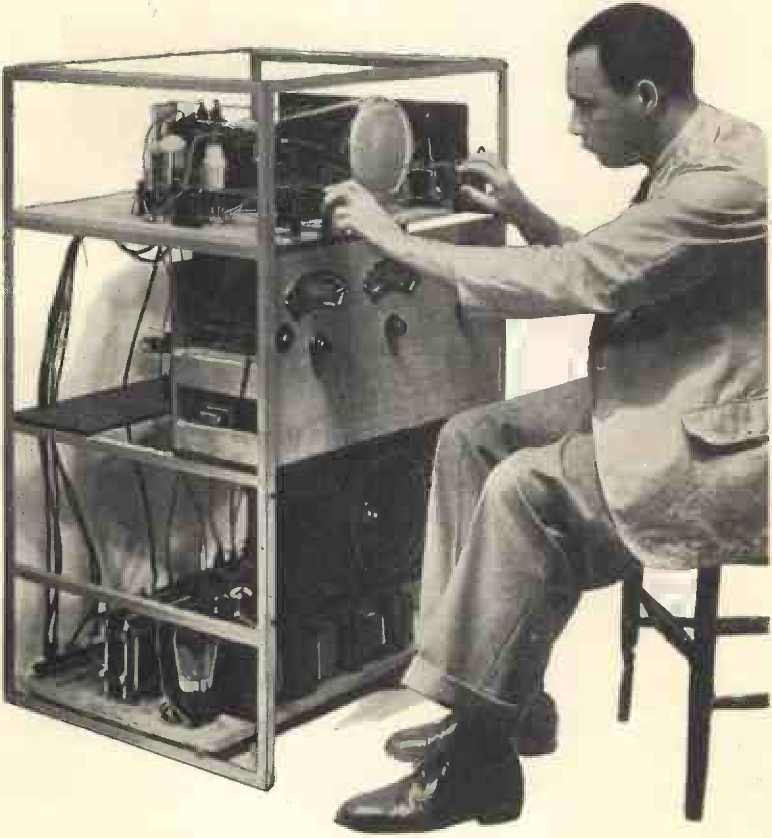
THE TIME BASE IS SHOWN HERE IN SITU WITH THE TUBE IN POSITION. ON THE FURTHER SIDE ARE ALL THE VALVES AND COMPONENTS FOR THE LINE SCANNING AND IN THE FOREGROUND ARE THOSE FOR CARRYING OUT THE PICTURE SCAN (SEE CHAPTER 19)

IN THE IRON CHASSIS



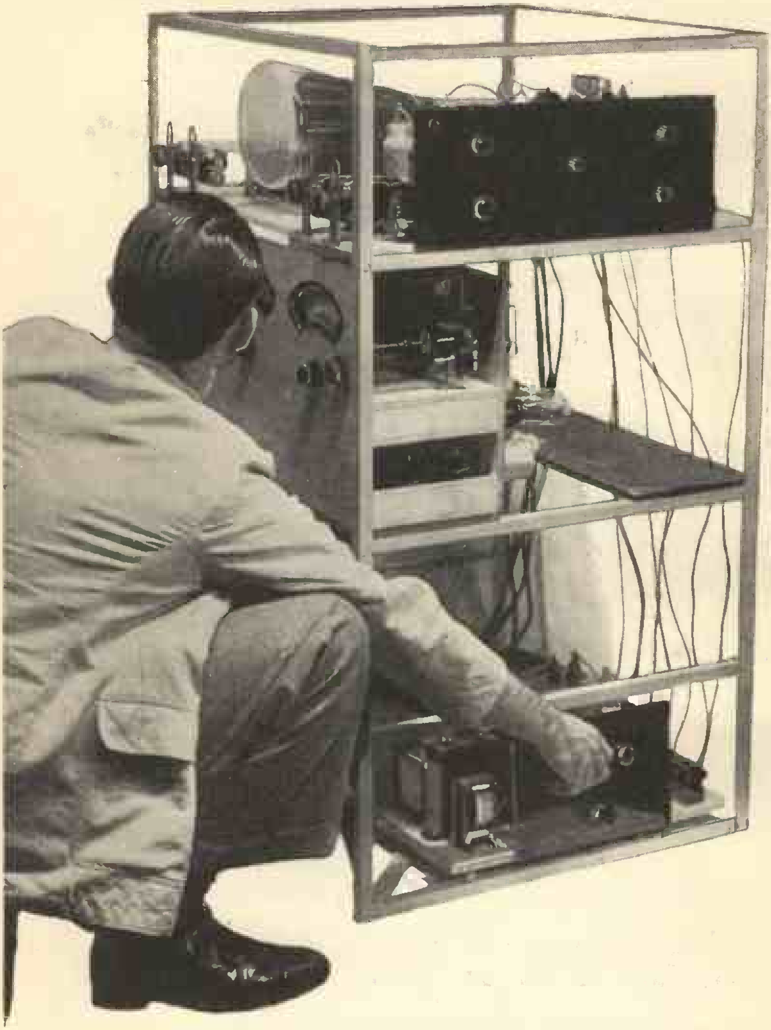
THIS IS A RIGHT-HAND SIDE VIEW OF THE TELEVISION CHASSIS WITHOUT THE RECEIVER PORTION IN PLACE. IT SHOWS THE TIME BASE AND POWER PACK CONTROL PANELS AND ALSO THE METHOD OF TAKING THE LEADS THROUGH HOLES IN THE WOODEN FLOOR OF THE RECEIVER COMPARTMENT

THE TIME BASE SPEED CONTROLS



ADJUSTMENT OF THE TIME BASE SPEED CONTROLS IS BEING CARRIED OUT HERE. OWING TO THE FACT THAT THE PHOTOGRAPH WAS TAKEN BY FLASHLIGHT THE RASTER ON THE TUBE IS NOT VISIBLE

ADJUSTING THE FOCUSING OF THE TUBE



THE SHIELD BIAS CONTROL IS BEING GRADUALLY INCREASED TO GIVE A SHARP PICTURE AND THEN THE RIGHT HAND KNOB (1st ACCELERATOR) WILL BE TURNED CLOCKWISE TO BRIGHTEN AND TO SHARPEN THE PICTURE STILL FURTHER

WHEN THE SYNCHRONISING FAILS TO WORK

A SCENE FROM A FILM THAT HAS BEEN TELEVISED WITH HORIZONTAL SCANNING FROM RIGHT TO LEFT. THE SYNCHRONISING HAS FAILED FOR A FRACTION OF A SECOND WITH THE RESULT THAT THE TIME-BASE LINE SCAN HAS "FIRED" TOO LATE, FOLLOWED BY A FEW LINES OF LATE SCANNING IN TWO PLACES. THE EFFECT IS MOMENTARY, OF COURSE, BUT IT CAUSES A JUMP TO THE RIGHT IN THE PICTURE, AS SHOWN

UNDER MODULATION

AN IMAGE OF A TELEVISED FILM AS SEEN ON A CATHODE TUBE WITH BAD UNDER MODULATION

TUBE PROPERLY MODULATED

THE SAME IMAGE AS ABOVE BUT WITH THE CATHODE-RAY TUBE PROPERLY MODULATED. THE PHOTOS WERE TAKEN BY VON ARDENNE, THE FAMOUS CONTINENTAL TELEVISION RESEARCH ENGINEER valves together. These go down to the two 1 amp sections of the time base transformer. The seven amp section is taken up through three double flex leads to three points on the time base so that the voltage drop in the wiring shall be negligible. Do not try to economise in this by using only one flex lead. The three are necessary, and so is the method of split feeding the filaments of the valves so that the power supply is evenly distributed. By this means loss of voltage is avoided. This method of feeding was discussed at the end of chapter 16.

For the connections between the units, other than the filament leads we have used high tension rubber flex. This is so spaced that no two leads touch each other, the leads being passed up to the time base from the power pack through holes in the board situated at the back of the set section of the framework. See Figs. 182 and 183.

The leads should be taken up at the back of the framework and then passed along under the time base baseboard and its iron sheet shield, and through the necessary holes to their points of contact.

THE L.T. SUPPLY

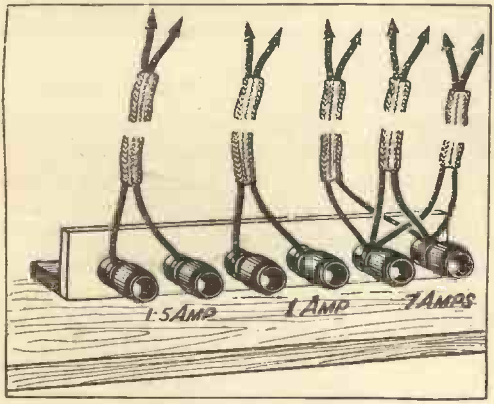


Fig. 182—The leads from the low tension end of the power pack are grouped as shown. The 1.5 amp wires go to the valveholders V2 and V2A ; the 1 amp to V8, and three parallel leads go up to the other connections marked 7a, namely to V3, V5, and V9

Electric-cable clips are used to keep the leads tightly in position on the under side of the time base baseboard.

Small spade ends should be soldered to the ends of the flex leads used for the connections to the four deflectors and to the accelerator and carbonised screen terminal of the cathode-ray tube. On no account should there be any suspicion of " whiskers " on the ends of flex leads. Such would easily cause trouble and should be avoided.

There are two points that need special reference. They are the resistance and holder on the back of the vertical piece of wood holding V10, for the cathode-ray tube, and the resistance block on the baseboard just in front of the same piece of wood.

The resistances in each case are held in position on clips with soldering tags. These are available in the form of a complete five-way block from Bulgin, and one of these blocks is made to do duty for both the resistances in front of the support and for the one resistance on the back surface of the wooden support.

The five-way block is sawn through with a hacksaw to form one of four pairs of clips and one of one pair. The latter is used on the wooden support and the other is employed for the three resistances on the baseboard. These are spaced so that there is a gap of one clip between the resistance going direct to earth and the other two.

H.T. AND TUBE CONNECTIONS

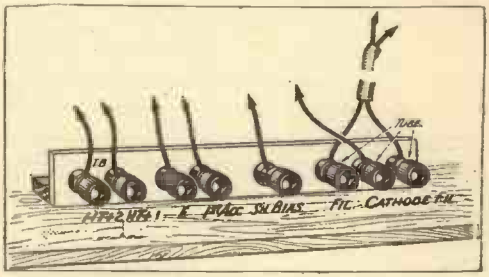


Fig. 183—Cathode-ray tube connections and the time base H.T. leads are connected as shown. H.T.+2 goes to component 48 on the time base. H.T.+1 goes to No. 36, E goes to E terminal, 1st Accelerator to "anode" socket of V10, Sh. Bias to the resistance No. 14, the filament terminals go to the filament terminals of V10, and the cathode terminal to the cathode of V10

The cathode-ray tube specified is the smallest type that is really useful for television, but a larger tube can be used quite well, the Ediswan CH being a good example. The rack and the valve-holder base will have to be modified, of course, to take the new tube, but the rest of the outfit, except the frame aperture on the cabinet, will not have to be altered.

K. D. R.

Chapter 20

OPERATING A TELEVISION RECEIVER

CONTROLS OF ULTRA-SHORT WAVE SETS—TUNING ADJUSTMENTS—ARRANGING AN AERIAL—PRELIMINARY TESTS—TUNING THE VISION SIDE—FINAL ADJUSTMENTS—CONNECTIONS TO THE TIME BASE—OPERATING THE TIME BASE—THE CABINET DESIGN—CHECKING THE VOLTAGES—SETTING THE CONTROLS—OBTAINING THE "RASTER"—INTERLACING.

With any set designed to receive such ultra-high frequencies as are employed in television broadcasting, it is undoubtedly a fact that success is dependent to a very much larger degree than is the case with ordinary wavebands upon the way in which the receiver is operated.

Tuning Adjustments. The three main tuning dials and two subsidiary controls are the controls of what are, in fact, two entirely separate sets, and the two on the left are used completely independently of the three on the right.

Concerning the purpose of the tuning controls and the way in which they should be used we shall have more to say a little later on. In the meantime, there are several points in connection with installation and initial adjustment to which attention should be called.

For the purpose of preliminary tests, it is recommended that the receiving part of the equipment should be regarded as a separate unit, and a mains lead should accordingly be fitted to the two appropriate terminals on the mains transformer.

Arranging an Aerial. The question of the aerial arrangements to be finally employed is one that will depend almost entirely upon the locality in which the set is to be used and the distance from the Alexandra Palace, and a certain amount of experimentation will therefore be inevitable.

But a start can be made with just one dipole aerial—the details of which can be obtained from another chapter in this book, and the ends of the flexible leads-in should be connected one to each of the two terminals marked "Aa."

To test out the "sound" part of the receiver is straightforward enough, for this can be done simply by connecting a speaker to the two terminals marked "sound output." But before a test can be made of the vision set—which is, of course, the superhet—it will be necessary to make a slight temporary alteration to the output arrangements in order to insert a loudspeaker.

For this purpose a standard type of L.F. choke will be required, and the method of connecting it in circuit is as follows. Leave the anode of the second detector, or output valve (the MH4) connected to one side of the 1-mfd. condenser, but break the wire which joins these two points to one of the 10,000-ohm resistances and insert the L.F. choke.

This is only a temporary expedient for testing out the set, and the modification should therefore be made having regard to the fact that the wiring is to be restored to its original position later on.

With the choke in circuit, a second speaker may now be connected to the two terminals marked "vision output," after which the preliminary tests of the set, or perhaps we had better say sets, may be commenced.

Preliminary Tests. In the case of the sound receiver, which is, of course, the straightforward detector and L.F., these preliminary tests are for the purpose of checking up (a) whether the detector oscillates quite satisfactorily and (b) the condenser setting at which the sound station is tuned in.

For this test you have only to concern yourself with the two controls on the left of the panel looking at the front. One of these is the tuning condenser and the other one—the smaller knob—is the reaction control. It is just possible that for the purpose of locating this station in the first instance it may be found an advantage to use a pair of 'phones connected to the "sound output" terminals. The procedure otherwise is exactly the same as for any other one-tuned-circuit-with-reaction receiver, except that in this case the dial must be rotated very slowly.

Tuning the Vision Side. Having located the station and the setting at which it is received, put this part of the equipment out of tune, and proceed to try to find the vision station on the superhet section of the receiver.

In this case, there are two main tuning dials to be concerned with, one for the oscillator (the dial in the centre of the panel looking at the front) and one for tuning. The knob on the extreme right is the variable-mu control for the first I.F. frequency valve, and it should be used in much the same way as a similar control on any ordinary set. As a matter of fact, the same thing may be said to apply to the two other controls—the tuning and the oscillator controls—for their functions are exactly the same as on any set employing similar controls. But, of course, in this case they must be used very carefully.

The variable resistance which is mounted on the vertical metal " baseboard " need not be touched at this stage, since that is only intended to be used when you are actually receiving pictures and is concerned with picture definition.

Final Adjustments. But before the outfit can be used for the combined reception of sound and pictures, there is one further test that it will be necessary to make. For these preliminary tests we have suggested the use of just one dipole aerial. Providing, with this arrangement in your particular locality, there is no interference with the " sound " by the " vision " station, and vice versa, the one aerial will be sufficient. But if interference does occur when each section is tuned to its respective station, then it will probably be necessary to use a separate dipole aerial for each section.

In this case, one dipole should be connected to the points marked " Aa " and " Bb " on the sound receiver, and the other to the two terminals correspondingly marked in the vision receiver. Under these circumstances, the wire in the set which at present joins the two " Bb " terminals must be removed.

When it has been ascertained that each section is working correctly, the L.F. choke in the vision section can be removed, the wiring restored to its original position, and the set can then be connected up with the rest of the apparatus.

The set should first be placed in the space provided for it in the framework and the mains lead joined to the side of the fuses remote from the mains in the cathode-ray power pack equipment.

Connections to the Time Base. The only other connections necessary are from the set " vision output " terminals to the time base input terminals marked radio and " E." As will be apparent from the terminal markings, there is a right and wrong way round, and it is important that the " E " output terminal on the set should be connected to the " E " input terminal on the time base. This latter terminal must also be connected to true earth. With regard to the other connecting lead, that is to say not the one between the two " E " terminals, it may be found necessary to insert a short wave H.F. filter in series, but that is a matter that will depend upon results, and it need not be included for the early tests. If, however, the picture appears to be suffering from interference, then it is probable that the use of an H.F. filter will help to eliminate the trouble.

Operating the Time Base. It is almost impossible to write directions for the operation of the time base that will enable you to go straight to it, turn a few knobs and sit back and enjoy the pictures. There is, of course, a right and wrong way to go about the adjustments, but you will have to get the " feel " of the outfit before you get the final adjustments right for perfect picture reception.

But before we go into the matter of knob twiddling let us say a few words about such things as magnetic screens, larger cathode-ray tubes, and also the cabinet design.

It may be necessary in some cases to fit a sheet of iron right along under the time base, to screen it from the radio receiver, and another sheet of iron below the radio portion, to screen it from the television power pack. These screens are just sheets of iron, 24 in. square and are screwed to the wooden " floors " of the sections concerned. The screens have to be connected to earth. The chassis itself should also be earthed.

As regards a larger tube, this is easily fitted if slight changes are made in the tube supports and also if the time base baseboard is lengthened. We suggest that to accommodate the Ediswan CH tube, which is 27 in. long, the baseboard be cut 24 in. square, except for the portion where the support for the cathode-ray tube valve holder is to be situated. Here the baseboard should project rearwards about 4 in. It will not necessitate the alteration of the iron chassis but will, of course, affect the cabinet, which will have to be that much deeper.

The Cabinet Design. Many of our readers will be skilled woodworkers, and they will probably take a delight in building the cabinet to surround the chassis according to their own designs. Others who prefer to buy the cabinet ready-made will be well advised to go to a reputable local cabinet maker, or else to such firms as Messrs. Peto Scott or other radio kit suppliers, who will build to order a cabinet to fit the chassis. The fact that the iron chassis is used makes the cabinet design extremely easy, for the whole outfit is intended to slide into the cabinet, which should have vignettes in the front to allow the controls to be handled, while a suitable viewing frame should be fitted to finish off the cathode-ray tube screen. A piece of "Triplex" glass in front to protect the tube is a good idea.

On the right of the cabinet, looking from the front, there must be two doors, or one large door, so that should any adjustment of the focusing of the tube, or the framing synchronising, or other side controls be required the door can be opened and the adjustment made. These controls will rarely want touching.

Before placing in the cabinet, however, the time base must be set, and it is a good plan actually to receive television pictures while the outfit is still in the chassis form.

Checking the Voltages. As mentioned in the previous chapter the voltages on the cathode-ray tube must be checked before the tube is placed in position, shield and accelerator voltages being taken between the grid and anode points of the valveholder V10 and the cathode terminal, and the second accelerator voltage being taken between the cathode and earth. The shield bias voltage should control between about 40 and 100 or more, the first accelerator between about 250 and 1000, and the earth-to-cathode voltage will be between about 1400 and 2500 volts. This latter is not critical.

The voltage controls are on the power pack panel, the top left being the shield bias (maximum bias to the right) the first accelerator voltage being on the top right, maximum voltage to the right, and the main accelerator voltage control is the bottom knob. See Fig. 184 below.

THE VOLTAGE CONTROLS

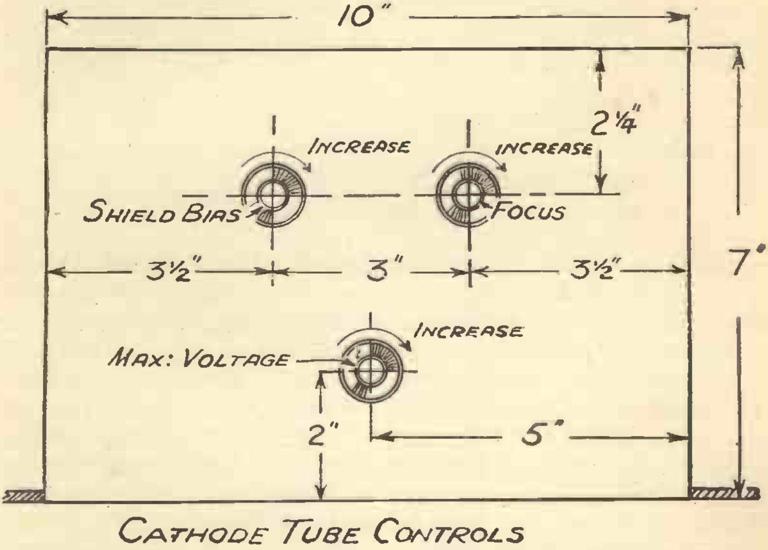


Fig. 184—Three controls are used on the power pack panel and they are placed as shown here

Having checked the voltages, and seen that the time base valves light up, and the gas-filled valve (V8) " flashes " wait a minute or two with the cathode tube still out of its sockets, and the deflector flexible connections placed so that the ends cannot touch anything. Watch the time base to see that the gas-filled valve continues regularly. You can alter the positions of the two left-hand knobs on the front of the set and see the effect on the V8. You will be able to "turn it out" by these knobs (Fig. 185).

You will probably hear a high-pitched faint whistle all this time. It comes from the multi-vibrator valves, V2, V2a, and V3.

Now switch off the whole set. Allow it a minute to discharge all voltages through the various potentiometers. Connect up the cathode-ray tube. Set the power pack controls to minimum in the case of the bottom one. The others should be set half-way round in the case of the top right control and fully round to the right in the case of the left-hand control.

THE MAIN PICTURE CONTROLS

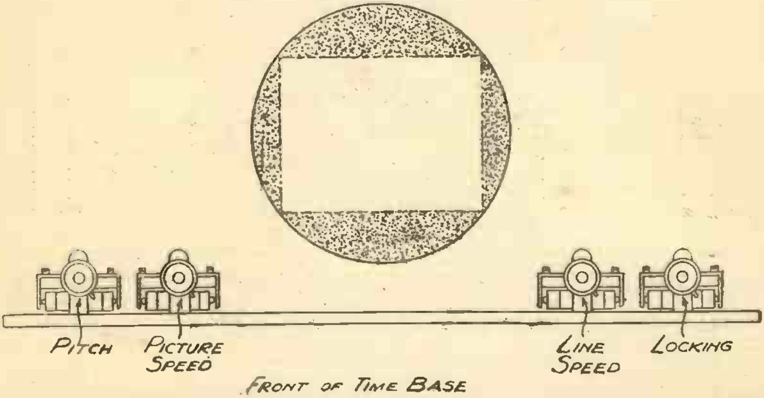


Fig. 185—The four controls on the front of the time base are shown here. They are mounted so that the spindles come forward to project through the cabinet when the outfit is placed in final position

Now switch on the power. The switch, by the way, is best fitted somewhere handy on the cabinet, or it can be left as a control on the wall socket to which the set is connected. We assume, of course, that the set has been wired so that its power transformers are connected correctly for the mains voltage to be used. And as the television set will take some 250 or more watts it should be used on a power plug if available, and not the lighting supply.

Setting the Controls. While the set is warming up, set the time base controls as follows. We are assuming that no television signal is coming through, so we set the resistance control at the bottom left of the time base panel about half way round. Fig. 186. Then we set the right-hand control in the front (Fig. 185) fully to the left. The 50,000 ohm potentiometer on the baseboard (B) is set about half way round (this should be done before switching on, by the way), and then we await events.

After a time the time base valves will warm up, and later still the power pack thermal delay switch will trip and you may see a line or series of lines on the front of the tube.

ON THE SIDE PANEL OF THE TIME BASE

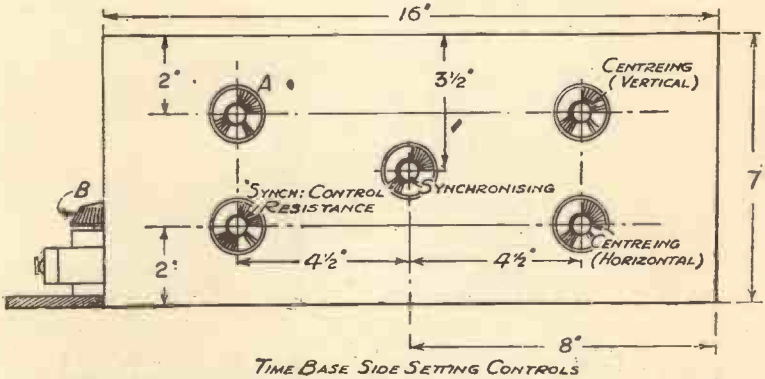


Fig. 186—The side panel on the time base has these controls on it. A is used in conjunction with the baseboard control B

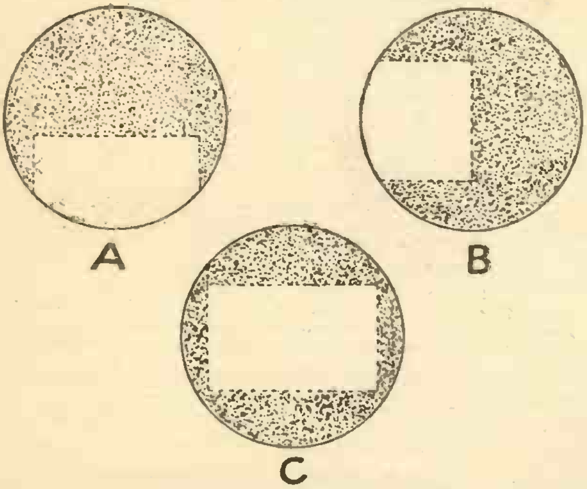
If nothing appears after a couple of minutes, and you can see that the valve MU2 in the power pack has a blue glow round its plate, you will know that the cathode tube is " on," but that the shield bias is too great to allow a spot to appear.

Reduce the bias slowly by turning the knob gradually to the left. The moment the spot or streak of light appears on the screen, stop turning and turn the right-hand knob slowly to the right. Continue until the spot or lines are fairly sharp, adjusting first the right-hand and then the left-hand knob, but *always keeping the latter as far to the right* as is conducive to sharp focusing. Always run the tube with the left-hand knob as far to the right as possible, for so doing lengthens the life of the tube, and the reverse effect is obtained if the knob is set too far to the left.

With the tube fairly well focused, well enough to allow you to see what is happening on the screen, set to work to set the rest of the controls.

Obtaining the Raster. Turn the left-hand of the right-hand pair of knobs on the front to the right fairly fully, and turn the two left-hand knobs to the right, altering their relative settings until you get a picture frame of light of proportions roughly six to eight. If it is not in the centre adjust the two shift or centreing controls on the side of the time base (right-hand knobs on the panel) till the " raster " is central Fig. 187.

Vary the left-hand knob of the right-hand pair on the front of the time base, and the top left-hand knob on the panel until the length of the scanning line (horizontal) is right. Probably the right-hand knob of the left-hand pair on the front will have to be turned to the right before the length is correctly held, while adjustments on the left-hand knob of the left-hand pair will also be required.



CENTRING THE PICTURE

Fig. 187—" A " shows the picture frame too low, " B " too much to the left, and " C " in the correct position. Alterations of position are made by the controls on the right of the side panel on the time base

When the raster is roughly right you can turn your attention to the tuning in of a television picture as described elsewhere in this chapter. With the signal tuned in you may vary the synchronising control and the time base knobs again until the raster appears steady and constant in appearance.

If it appears to have a bright line on the left-hand side (Fig. 188) the deflectors A1 and A2 should be reversed—the tube is being scanned the wrong way. The white line should be on the right-hand side, and the picture on decreasing the speed by turning the right-hand of the left-hand pairs of knobs to the left should appear to be " flashing " upwards.

If you are in a good position for radio reception of television you should on receiving a picture be able to turn the bottom knob of the left-hand pair on the panel of the time base completely to the right. If the signals are not very strong you will have to have this knob turned a little to the left. You will soon see by the picture " holding powers " of the time base how much the knob wants turning.

The modulation of the picture—that is its strength—is controlled by the volume control on the receiver. If it is turned up too much the picture will be too black, and if not enough, the picture will be badly defined.

Streaks and blobs on the picture may mean that too much volume is being used, or that the synchronising control is too far round to the right.

CHECKING THE SCANNING DIRECTION

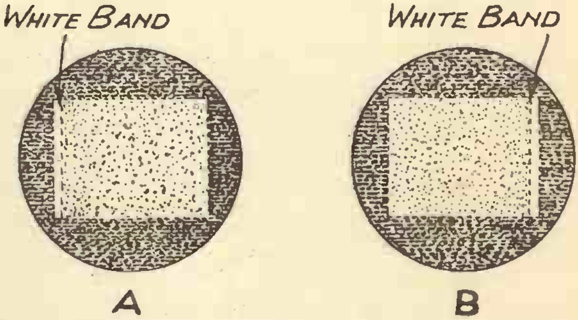


Fig. 188—If your raster appears as in "A," with a thin white line on the left of the screen you have the tube scanning the wrong way and must change over the connections to the horizontal deflector. The raster should be as in "B"

It is impossible to tell you exactly what to do right from start to finish. The best teacher is experience, and we advise you, after getting the raster reasonably correct as per instructions, to experiment for yourself. There is no need to alter the tube power pack adjustments after the sharp bright image of the tube has been achieved. Just "play" with the controls on the time base, one at a time, returning to the previous setting each time as you find out exactly what each control does. It is the best way to learn how to control the television receiver.

Interlacing. Finally, a word about interlacing pictures. The E.M.I. system is to use interlaced scanning. This is somewhat different from the ordinary straight type. The present time base will deal with it quite successfully, but it may want a slight alteration. This alteration cannot at the moment be discussed as the full details of the system to be used are not available at the time of writing, but those who build the outfit should keep in touch with the Editor of this book when details for modifications and the method of switching from Baird to E.M.I. reception with the time base will be explained to correspondents as soon as details are available.

A last word. Do not make any internal adjustment, or change any connection, and this includes voltmeter connections, while the power is "on." Always switch off and leave for one minute before delving into the interior of the set in any way.

K. D. R.

Chapter 21

A GUIDE FOR TELEVISION SET BUYERS

CATHODE-RAY OR MECHANICAL SYSTEM ?—SIZE OF RECEIVER —PRICE CONSIDERATIONS—EASE OF CONTROL—SINGLE OR DOUBLE-CHANNEL SETS ?—DIRECT OR REFLECTED VISION ?

The final choice of a television receiver from the various types and prices of sets that are available on the commercial market must always, and obviously so, remain with the prospective purchaser. We can in this chapter give one or two hints as to what to look out for and what to avoid in the choosing of your first high-definition television receiver, but the final choice remains with you.

Cathode-Ray or Mechanical ? There are two main divisions in television receivers ; the cathode-ray type and those that are operated on what is called the mechanical system. Which is to be the better of the two to choose, provided that a good selection of either is available ?

That is difficult to say. Both have their advantages and disadvantages. The question of size and cost we will deal with later, but in this part of the chapter we can well raise the point of noise of operation, and flexibility (Fig. 189).

Noise of operation is completely absent in the cathode-ray type of receiver, but, owing to the fact that the mechanical type of viewer requires moving parts, there is always a risk of noise with this type of machine. The noise should not be obtrusive, or in our opinion the receiver is not worthy of consideration, but you will have to bear in mind the question of noise and how much will be noticeable when you have the set at home in a quiet room.

Someone will be sure to say now that the sound programme will drown any motor hum. It might do so; but the effect of pauses in the sound, such as occur in news-bulletins, and in drama and the like, will be ruined if a bad motor hum is immediately audible from the vision side of the set. So bear in mind this matter of noise when considering the receiver, and when hearing and seeing one prior to purchase. You will naturally want a good demonstration of your viewer before clinching the deal, and the final demonstration should be at your home if possible.

What is meant by flexibility is the ease with which the set can be adapted to include any slight modifications that may be introduced as the art of television and its technique advance. Television is sure to develop rapidly, and you do not want to have a set that may soon be obsolete, unless there is a reasonable arrangement offered by the manufacturer to modify or replace the set as and when the necessity arises.

SUGGESTED LAYOUT FOR MECHANICAL SCANNER

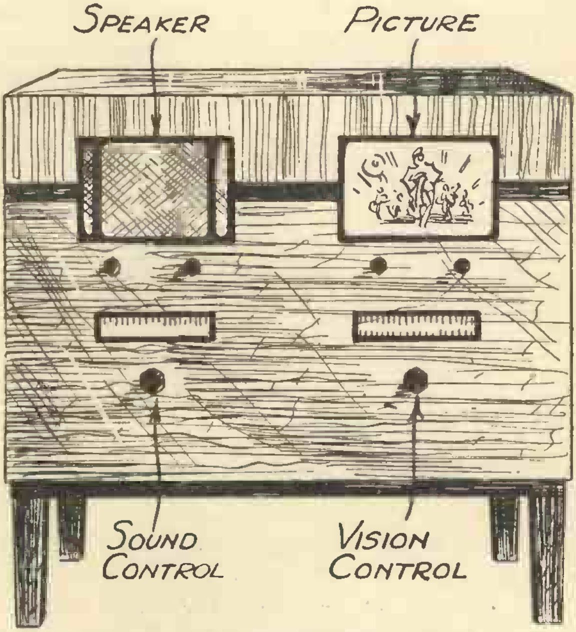


Fig. 189.—A design of television receiver using mechanical scanning. The vision side has to be well compartmented off and fairly sound proof in order that no motor hum or whir shall be audible to the " looker "

By modification we do not mean that should any slight advance be made which gives, perhaps, better quality pictures you should at once expect the manufacturer to include the circuit change in your set. That sort of thing is never done in ordinary radio sets, and can hardly be expected.

But if a transmission change is made and if this renders your set obsolete and useless, then something ought to be done about it on reasonable terms. That is a point that should be inquired about when you purchase your set.

The question of the life of the " vitals " of the set should also be gone into with the dealer. By this, we mean the cathode tube if one is used, or the projection lamp and other things in the mechanical type of set ; the valves, and so forth. Also find out what happens in the way of service. This is most important, for a television set cannot be serviced by any Tom, Dick, or Harry. The local cycle man may be able to put your ordinary radio set right for you, but we doubt his ability to service television receivers should anything go wrong.

Size of Receiver. The size of the television receiver will depend on several things. First, it will depend on whether you want a big picture or a small one (Fig. 190). That is obvious ; and though at first the size of picture may not seem to be very large, as television gains ground the possible size of the image will assuredly increase.

COMBINED SET WITH LARGE SCREEN

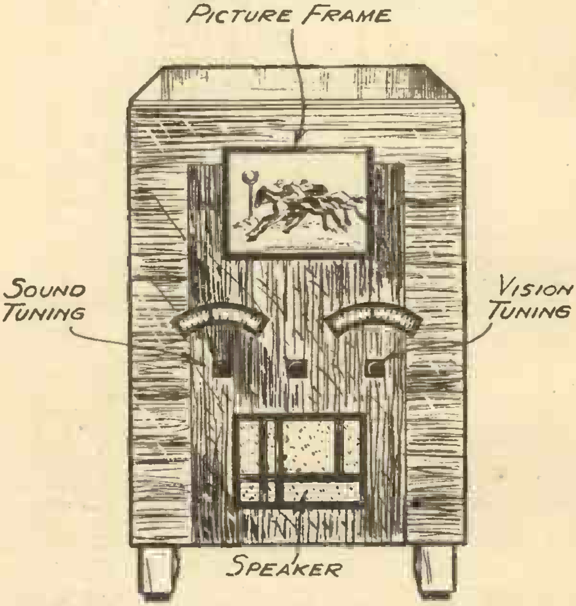


Fig. 190.—A large cathode-ray tube giving a twelve-inch picture is shown here in a cabinet design that is reminiscent of the popular radiogramophone. The centre knob controls the brilliance of the picture. The framing control and the change-over switch for the two systems are on the side

Now with a mechanical receiver the size of picture will probably not mean much extra in the way of running cost, though the initial cost of the set will naturally be greater than that where a smaller image is provided. But in a cathode-ray set the cost of running, in the form of the cost of cathode tube replacements may be very much greater in the case of a large picture receiver than in that of the one giving a smaller screen. That is worth looking into when you make your choice.

We are not going to be dogmatic about this, but raise the point because it is one that you should raise yourself with the dealer when choosing the set. After all, a cathode tube costs money, and it is not immortal, and as a big tube costs more than a small one to replace the question of size must be borne in mind. There is no sense in getting a set that will give you a large picture if a small one will do you quite as well.

The size of picture you want will depend on the size of your family for the most part and the size of room in which you will install the set. This has been discussed in a previous chapter, so we need not go into it here. But don't forget it when choosing your television receiver.

There is another sort of size to be considered, too. That of the dimensions of the receiver itself. A pedestal model (Fig. 191). is probably the most convenient if you have room for it. If not you may prefer one of the table types, perhaps having vision only in it with another set for the sound. In this latter case you could run the speaker round by an extension wire so that the sound came from behind the vision set, thereby obviating the need for having the two sets close together. But more of that later (Fig. 192).

A MODERN TYPE OF TELEVIEWER

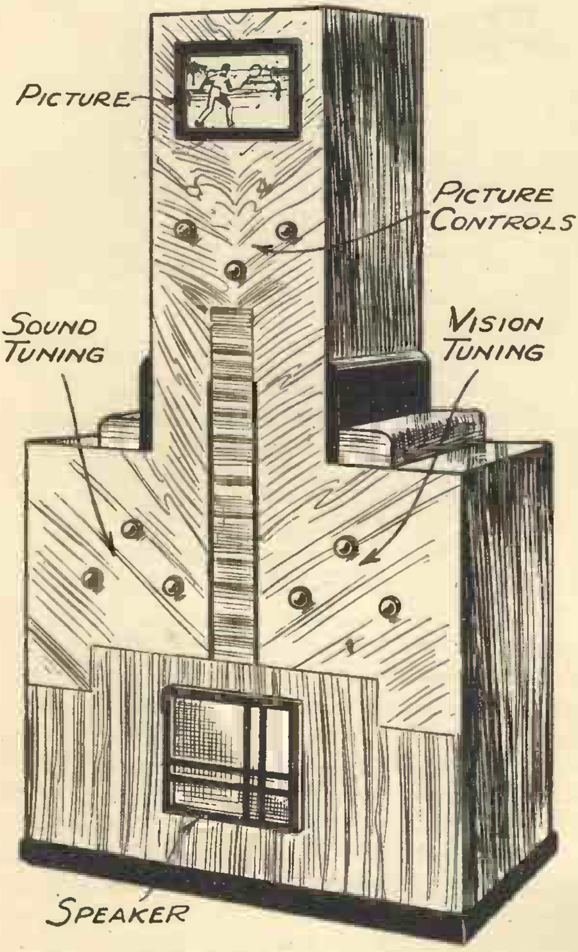


Fig. 191.—An up-to-date design for a pedestal type of cathode-ray combined vision and sound receiver

Price Considerations. The matter of price will depend on so many things that we cannot say much about it here. The cost of the set will naturally depend on the type of set ; its excellence, for not every set will be alike in the quality of picture it will give, any more than are sound radio sets alike in their loudspeaker reproduction, and the size of picture that the receiver will give.

This latter point we have already enlarged upon. The matter of type of set we have also discussed to some extent, though we shall have something to say about various modifications later on. The other point, that of quality of vision, must rest with the purchaser. He must see a demonstration and satisfy himself about the quality of picture, and of the accompanying sound, that the set he thinks of buying provides. Remember that if the quality is not to your liking when the set is first demonstrated there is no likelihood of it improving with use.

RECEIVER FOR VISION ONLY

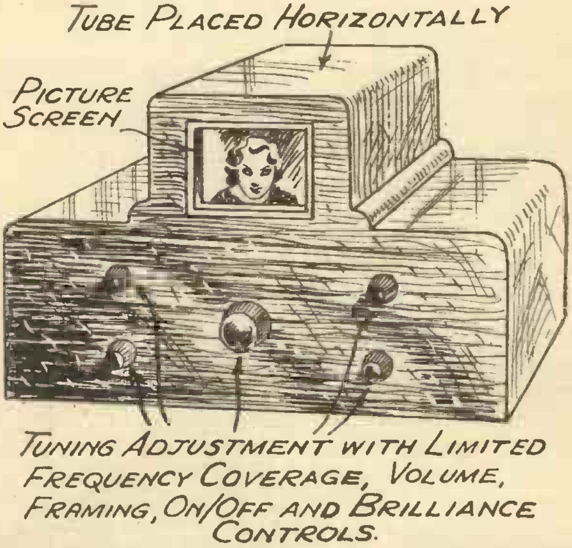


Fig. 192.—The table model viewer using a cathode-ray tube. This set necessitates a separate receiver for the sound part of the programme

A television set is not like a motor car ; it will not get better as it is " run in." Look upon it just as you would an ordinary wireless set, no matter whether it is a cathode-ray or a mechanical viewer.

Ease of Control. And now we come to what is perhaps the most important factor of all ; ease of control. Remember that television is not the mere reception of a sound broadcast ; it is a reception of sound, and, what is more tricky to receive, properly synchronised vision.

Not synchronised only in the same way as the talkies, i.e. the sound with the vision. That is done for you at the transmitter and cannot go out of synchronism. What can slip up is the synchronisation of the various bits of the picture, and unless the set you choose is easy to manipulate you may have a difficult time "fitting the bits together," as it were.

We do not want to paint a terrible picture of knob juggling and of tearing of hair when the set refuses to assemble the televised jigsaw. A television viewer worthy of the name will not give you all that perturbation, but it will have to be controlled by you up to a point, and the degree of control required will depend on the individual design of set.

That is the important point. You want to choose a set that, other things being satisfactory, is easy to control. Not one with dozens of knobs that have to be varied each time the set is switched on. We have drawn a lurid picture perhaps, but any exaggeration on our part must be excused as our anxiety to drive home the realisation for the need for easy adjustment (Fig. 193).

PROVIDING EASY PICTURE CONTROL

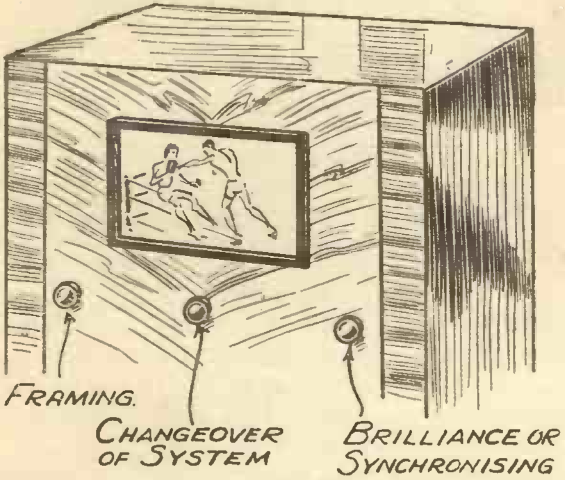


Fig. 193.—Some idea of the simplicity that can be reached with a carefully-built commercial receiver will be gained from this sketch. Below the knobs shown are just the receiver controls, which can consist merely of a vernier tuning adjustment and combined volume control and on and off switch

We know how wonderful television can be, and we also know how terrible it can be if the set on which one is trying to receive it wants coaxing like a spoilt child. So when you have your demonstration insist on the demonstrator allowing you not only to "tune in" but to throw out of adjustment every knob that is get-at-able in ordinary use, and then see if you can get the pictures back.

Remember that at home some member of the household is going to twiddle every knob, and if when you return home (to find every adjustment upset) you cannot re-set the receiver, that television viewer is not going to be any use to you.

Single or Double Channel? By this we mean complete sound and vision or separate sound and vision receivers? It does not matter which arrangement you have, but you must have both if you are to enjoy television. It is no good having just the sound, and hardly better to have only the vision section. Both are necessary for full enjoyment.

The combined instrument will, of course, be larger than the vision or sound set alone, and will cost more but it will be compact and probably generally more satisfactory than having separate receivers.

The advantage of separate sets is probably only noticed when room is scarce and it is desired to use table models and to have the sound section with an extension lead to the speaker.

Direct or Reflected Vision? There are two main types of television sets on the market, apart from mechanical or cathode-ray types. These can be divided into the reflected and direct vision categories (Fig. 194).

There is not much to choose between them. In cathode-ray reception perhaps the reflected vision is in its impression a little more like the home cinema (if that is a recommendation) than the direct vision type, but apart from that and the fact that usually it is possible to get bigger pictures in the reflected type of cathode-ray receiver (because they fit bigger tubes to that sort of set) there is nothing in it. K. D. R.

THE REFLECTED IMAGE TYPE

Fig. 194.—A reflected image is shown here. The cathode-ray tube is mounted vertically and a mirror reflects the picture so that it is viewed horizontally

Chapter 22

TELEVISION FAULT FINDING

THREE MAIN SOURCES OF FAILURE — AMPLIFIER TROUBLES—AMPLITUDE AND FREQUENCY DISTORTION—PHASE DISTORTION—PLASTICITY—LACK OF "BASS"—LACK OF "TOP"—TIME BASE AND TUBE TROUBLES—FAILURE TO FIRE—"SPARKING" OF DISCHARGE TUBE—HICCOUGHING—MISFIRING—MISTIMING—WRONG SPEEDS—OVER MODULATION—UNDER MODULATION—FAILURE TO FOCUS—OVER FOCUSING—UNDER FOCUSING—NEGATIVE PICTURE—INTERFERENCE—A.C. HUM—STATIC "SPLASHES" —HETERODYNING.

There are three main sources of trouble in the television viewer. The first is the radio portion, or amplifier as it is generally called. The second is the time base and the tube itself, including the power packs associated with that part of the outfit. The third is interference, such as A.C. hum and causes which are often beyond the control of the owner of the television receiver.

Amplifier Troubles. Any form of trouble in the television amplifier, on the radio or so-called low frequency side, will have its effect on the screen of the television tube. It may not be noticeable until the picture is actually being received, but if there is any distortion or any mains hum it will be noticeable as soon as the programme starts.

Amplitude and Frequency Distortion. There are three main forms of distortion that may occur in an amplifier. There is frequency distortion in which certain frequencies are amplified to a greater or less extent than others, and there is amplitude distortion, in which the wave form of the notes, or signals, are not faithfully copied by the amplifier, and loud notes, for instance, may become distorted while soft ones come through "safely."

These two forms are present and noticeable in a sound amplifier, so that you can judge that their presence in a vision amplifier is particularly deadly.

Phase Distortion. The third form of distortion is also present in sound amplifiers, but does not usually make itself heard. In vision amplifiers, however, it can cause quite a lot of trouble. It is known as phase distortion, and is usually a " friend " of frequency distortion. It is the result of time as applied to electrical circuits and frequencies.

SIMPLE FORM OF PHASE DISTORTION

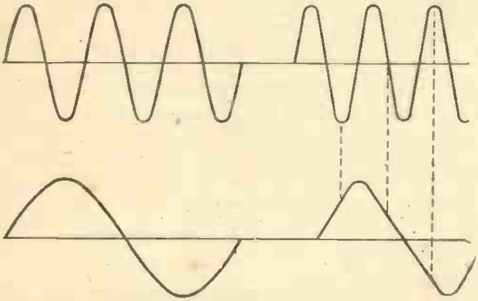


Fig. 195—The lower frequency has " started out " with peaks and troughs in phase with those of the higher frequency. But it has been caused to lag, with the result that in the right hand part of the diagram we see the lower frequency out of phase with the higher one

Suppose, as in Fig. 195, we have two signals sent out by the transmitter in the form of two waves, one of higher frequency than the other, but so in step that peaks and zeroes coincide as shown in the first part of the diagram.

Now, let us look at the second part of the diagram. The two waves have arrived through the amplifier in the receiver, but the timing is different. The one of lower frequency is now no longer coincident as regards the peaks and troughs of the other. It is " late." Phase distortion has taken place due to some unwanted effect of inductance and capacity.

While such an event would not be heard in a sound amplifier's reproduction, it is disastrous when it is present in a vision amplifier.

Plasticity. The usual effect of phase distortion is to form a double image on the screen, the picture being outlined in duplicate, giving what is known as the " plastic " effect. It is recognized by the outline being not only in black but also followed closely by a white line Fig. 196.

Especially is the plasticity evidenced when the picture is a contrasty one, with sudden changes from white to black as the scanning lines go across it. Then the phase distortion will cause very peculiar effects, due, it is said, to distortion of the transient voltages generated at the transmitter when the scanning switches from black to white, and vice-versa. These voltages are phase distorted by the faulty receiver, with the peculiar double effect.

The effect of amplitude distortion is also to cause false outlines, but generally it is noticeable in the lack of detail combined with excessive contrast. Not quite the effect of over-modulation, which gives a soot and whitewash effect, but a definite over-contrasting of the blacks and whites with a hazy formation of the greys.

Frequency distortion is generally not so prone to appear in a moderately well designed amplifier except as a falling off of high or low notes, or perhaps of both. It is not likely to occur in the middle of the spectrum, but may easily be present after about 6,000 cycles or below 70 cycles. And the presence of the frequency distortion, or falling off of amplification (there may be one or two peaks elsewhere as well), is disastrous to the picture quality.

THE DOUBLE OUTLINE

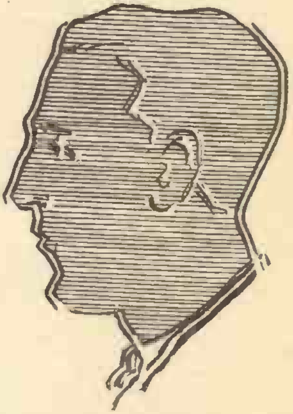


Fig. 196—A simple sketch illustrating the effect known as plasticity

Lack of "Bass." Lack of bass will make itself seen whenever there is a long patch of black in line with the line scanning. Thus in Plate No. 60 we show a vertically scanned picture with a long "run" of black up the man's coat. At the two longest unbroken runs of the scanning lines we see the picture has gone grey instead of black. That means that the amplifier has not been capable of giving full amplification of the lowest frequencies used by the transmitter and sent out during the televising of the long, black parts of the picture.

Lack of "Top." If the high frequencies are not well reproduced there will be serious lack of detail. Places where the scanning is crossing small pieces of black and white, such as a check skirt, will not come out properly. They will be inclined to be a very light grey and will appear as a plain piece of scanning instead of a pattern.

The television amplifier, unlike the sound amplifier for ordinary broadcast reception, must be capable of covering a frequency spectrum of from at least 40 cycles to 2 million cycles. And this must be done without any serious cut-off at either end.

Time Base and Tube Troubles. The first thing to do on setting a television receiver going for the first time, as you have read, is to switch on the tube and time base, with the tube bias control fully negative to cut off the beam. Then when the time base is operating, as you can see by the flashing of the gas discharge tube, the cathode-ray tube bias can be cautiously decreased and the tube focused.

So we will start this section of the chapter on faults by considering one or two points about the time base, points that can be judged before the cathode tube is working. The first is the action of the gas discharge tube. If there is not one in the time base, then this part of the chapter is not applicable. But most bases have one discharge tube, for the picture scanning.

Failure to "Fire." If after warming up the tube refuses to "fire," then something is wrong with the H.T. supply or with the circuit, or else the bias control of the tube is set too far to the negative side. Try reducing this first. Then if there is no firing, suspect the circuit itself.

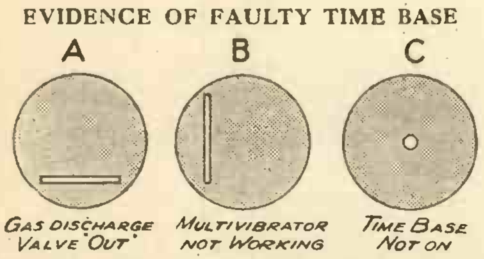


Fig. 197—Three cathode-ray tube screens showing the effect on the electron stream when a faulty time base is used

If the high speed portion of the time base works and not the low speed you will get a line as in A of Fig. 197. If the slow or picture scan operates and not the line scanning you get B, and if the time base does not work at all you get a stationary spot as in C.

If this latter happens switch off at once or you will burn the screen of the cathode-ray tube.

If the tube is not controllable for speed the bias and or the H.T. feed arrangements through the pentode or other means are probably at fault, or there is a fault in the circuit or components.

"Sparking" of Discharge Tube. Sometimes the discharge will take place quite well, but the increase of bias over a certain point will result in the discharge stopping and being replaced by a display of fireworks in the discharge tube itself. This takes the form of a series of stars or sparks flying from the anode to the glass,

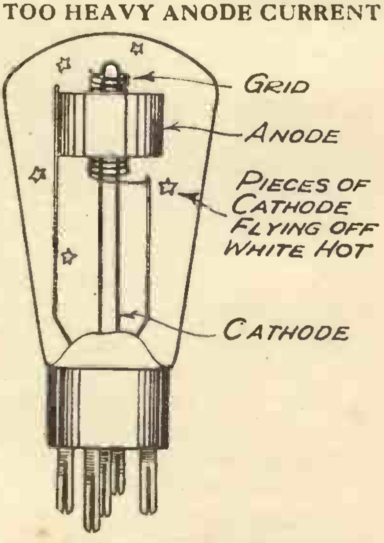


Fig. 198—This sketch shows the appearance of the gas-filled discharge valve when the anode current discharge is too great

and must be stopped at once by releasing the bias and allowing the normal discharge to continue (Fig. 198).

The reason for the fireworks is the dragging off of particles of the cathode during momentary discharges of colossal current (Fig. 199). The cure is to insert a resistance in series with the anode of the discharge tube. The time base described in this book has one of 500 ohms inserted for the same reason. It keeps a check on the maximum current through the tube during the discharge.

Now, assume the tube is discharging well, and that it is controllable for speed. Reduce the bias on the cathode-ray tube slowly and see what happens when the spot appears.

On occasion it may be found that on the thermal delay in the cathode-ray tube circuit going over a spot appears on the end of the tube with an area of about one inch (Fig. 200). If it immediately begins to melt away, do not worry; it is just a sign that the bias on the tube is excessive, and it can be left like that while the time base is examined.

If the spot does not immediately die away switch off at once; it means you have a break in the bias circuit and no bias is being applied to the tube. The latter is in danger of being burnt out.

CATHODE DISINTEGRATES

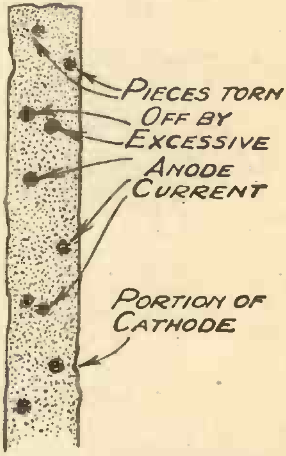


Fig. 199—A "close up" sketch of the cathode of a gas discharge valve that has been subjected to too heavy an anode discharge current, resulting in pieces being torn off the cathode

SHIELD BIAS

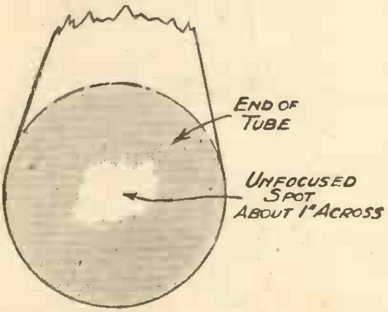


Fig. 200—How the spot appears on the end of the tube if no bias is applied, or momentarily if very much bias is applied

If you have doubts about that spot, switch the set on with the time base rectifier valve removed from the holder. The large spot will then appear in the centre of the tube. Watch it with the hand on the on-off switch, and switch off if the appearance is anything but momentary.

It is best to test the bias on the tube with an electrostatic meter before any switching on is carried out. It should read a maximum of anything above 60 volts.

A word about the MU2 valve. If this shows signs of an electric discharge like tiny reddish-white sparks flying across from cathode to anode switch off and change the valve. It is usually a sign of H.F. oscillation at about 1½ metres and may cause damage to the power transformer if allowed to continue Fig. 201.

H.F. OSCILLATION

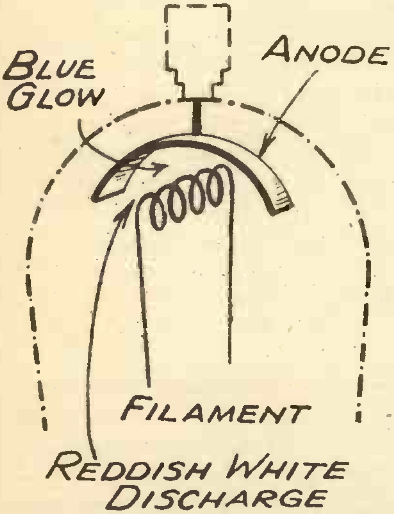


Fig. 201—The blue glow in an MU2 valve is normal, but the reddish-white discharge is not. If this appears the valve should be changed—it is oscillating at H.F.

But to get back to the time base faults. Assuming the discharge valve or valves are going correctly as far as can be seen at a glance, how can we check the accuracy of the scan by looking at the screen of the tube ?

If both portions of the time base are " firing " the result will be the white frame of horizontal lines which forms the so-called " raster." This should be even at the edges and with quite square corners. Its size is adjustable by means of the speed and pitch regulators on the time base, and by the deflector-setting potentiometers.

If the raster is over to one side, it means that the horizontal deflector setting is out, and if it is too low, it means that the vertical setting is amiss. (See previous chapter.)

If the raster is not too good in shape, and if it seems to be irregular, probably one or other or both the sections of the time base are misfiring, or else there is some irregularity about the H.T. supply. Perhaps there is an A.C. ripple on it, causing the line to become wavy (Fig. 202.)

A.C. INTERFERENCE

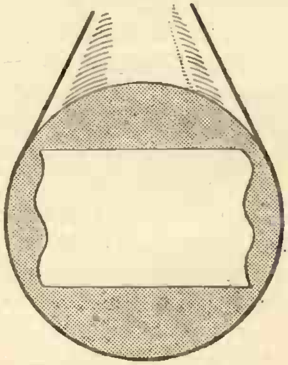


Fig. 202—Showing the curved outer edges due to the presence of A.C. ripple in the time base

Hiccoughing. Another reason for bad outline is hiccoughing of the gas-filled discharge valve. This is a process that occurs if the grid resistance is too high and does not allow the valve to come back to its normal state at the end of the discharge. The result is that when the condenser begins to charge again the valve almost immediately discharges once more, after which it will proceed to allow the proper voltage to be reached before the discharge takes place.

If a valve is hiccoughing there is no hope of getting a proper picture, for the timing will go awry.

Misfiring. Misfiring is another fault that may occur at any time in the time base, especially where gas-filled valves are used. The effect on a picture is that of the lower part of Plate No. 62. Here a vertical scan is being carried out, and the scanning lines are not always starting early enough. The result is white splashes on the picture.

Mistiming. Another form of " missing " can be seen in Plate No. 57. Here we have the synchronizing trip on the end of the scanning line (right to left) of a horizontal scanning picture out of timing for a short time. The discharge valve is running late. The result is that it is out of step with the picture for a few lines, and so the picture is pushed over to the right.

This type of thing is not infrequent in some cases where gas-discharge valves are used for the line scanning. It is usually caused through missing a synchronizing signal, causing the valve to fire late, after which the timing slips for a bit. The valve is behind time and starts late for a few lines, until the synchronizing pulls it in again. It is not likely to cause a steady deflection of the picture, as shown, but will cause a sudden momentary jerk. The illustration merely shows what has occurred, and is not intended to give an impression of a steady fault.

Wrong Speed. Wrong setting of the time base controls, or wrong values of resistances and condensers, may result in the scanning being at the wrong speed, either in the line scan or in the picture scan. If the speeds are far out from correct no picture or semblance of picture can be seen. But if the speeds are nearly right, then the picture begins to take shape, and when the speeds are correct you have the complete picture.

It is possible, however, to get more than one picture, or rather image, at a time. Sometimes two appear, as shown on Plate No. 62. Here we have the line scanning in a vertical-scan picture running at half the correct speed, while the picture scanning is correct. Detail will not often be as good as that shown, but occasionally it is remarkably good.

If the picture scan is at half speed and the vertical scan is correct, there will be two pictures on top of each other, assuming vertical scanning is used. With both picture and line scanning at half speed four pictures are seen.

Over Modulation. A picture with furry edges and heavy contrasts often means too strong a synchronising impulse, while one with a soot and whitewash effect with heavy black and white and no detail denotes that the modulation of the shield of the cathode-ray tube is too great.

Under Modulation. The opposite, namely under modulation, will give a very weak picture, something after the style of Plate No. 58 (top picture) which, on increasing the modulation, becomes more like the lower picture.

Failure to Focus. On rare occasions the cathode-ray tube will not focus properly. This is due to faulty voltage on the bias and first accelerator or focusing electrode.

Over focusing gives a very clear impression of the scanning lines and breaks up the picture into its strip elements too much. Under focusing does the opposite—it makes the picture too indefinite.

Negative Picture. There are two more points that can be mentioned here. One is the negative picture, in which blacks come out white and white appears black (Plate No. 59). This is usually a fault of design, and means the whole voltage polarity of signal supplied to the tube is wrong.

In high definition work the cure is the addition or subtraction of a stage of L.F. amplification, or the change of the second detector from leaking grid to anode bed rectification, or vice versa.

A waggly edge to the raster, one or more black lines across the raster (in the line-scanning direction), shaking edges to the picture images go to show that there is A.C. in the set or in the time base. Fig. 202 shows the waggly raster. Plates 60 and 61 show the effects of A.C. on vertical and horizontally scanned pictures.

If the picture scan is running at 50, and the mains are 50-cycle mains, you will get one black band. If the picture speed is 25 and the mains are 50-cycle, you will see two black bands.

Outside interference, especially if induced into the amplifier (or receiver) will cause splashes of white or black on the picture. They give the effect of rain running down the picture in the case of vertical scanning (see top half of left-hand picture Plate 62) or of horizontal splashes in the case of horizontal scanning.

Heterodyning from another station will cause a most interesting pattern all over the picture, the pattern varying with the pitch of the heterodyne. It is usually like a honeycomb or wire mesh effect.

K. D. R.

Chapter 23

STEREOSCOPIC TELEVISION

" PLASTIC " VISION—HOW THE STEREOSCOPIC EFFECT IS PRODUCED—THE ANAGLYPH—THE TELEVIEW SYSTEM—STEREOPHONIC BROADCASTING—A CATHODE-RAY SYSTEM—AT THE RECEIVING END

The stereoscopic effect is a term which has been coined to describe vision in three dimensions. It allows us to see depth as well as length and breadth, and to realise the relative distances of different objects by the way they stand out in relief. We owe this gift to the fact that our two eyes are spaced a little apart from each other, so that one eye views the same thing from a slightly different angle to the other.

If, for instance, we examine an object at fairly close quarters, first with the right eye alone, and then with the left, we find that one eye is always able to see a bit farther " round the corner " than the other, even when the head is kept perfectly still. The two separate impressions so obtained are automatically merged by the brain into one " plastic " or three-dimensional picture.

How the Stereoscopic Effect is Produced. In the case of a painting or photograph, the whole field of view is confined to a single flat surface, and although the laws of perspective help to give a certain effect of depth, it is never fully convincing. This is because there are no " corners to see round." Both eyes see exactly alike, and the brain can therefore only register a " flat " result. To create an effect of depth on a flat surface, it is necessary to have two separate pictures, one for the right eye and the other for the left, and to so arrange matters that each eye can see only that picture which " belongs " to it.

This is the secret, for instance, of the ordinary stereoscope. Two shots of the same scene are taken simultaneously through lenses spaced apart by the same distance as the eyes. The resulting photographs are then set side by side, and viewed through two separate eye-pieces each consisting of a wedge-shaped lens, as shown in Fig. 203. In this way the eyes receive two distinct impressions, and merge them together to give a life-like effect.

The Anaglyph. An arrangement, known as the Anaglyph, has been used to give three-dimensional effects in the cinema theatre by projecting two films on to the screen simultaneously, one in red light and the other in green. The audience views the screen through spectacles fitted with red and green lenses, so that one picture is seen only by the right eye and the other by the left, the effect of the combination being as before.

VIEWING ARRANGEMENT

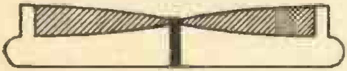


Fig. 203—Stereoscopic photos are viewed through two separate eye-pieces, each consisting of a wedge-shaped lens

In a modification of the same principle, two pictures are projected on to the screen through two Nicol prisms, similar to those used in a Kerr cell, so that the light which carries one set of pictures is polarized in a different plane to the other. Again the observer must use special spectacles, but this time the eye-pieces are differently polarized so as to pass the two pictures to separate eyes.

The Teleview System. In the so-called " Teleview " system a stereoscopic effect is produced by throwing both pictures on to the screen alternately, instead of simultaneously. The observer looks at the screen through a rotating disc with cut-out sections which expose each eye in turn. Finally, there are methods which depend upon the use of a special screen " backed " with a series of lenticular ribs or corrugations, which reflect the pictures back directly with the eyes of the observer. This produces the required " plastic " effect without the necessity of using spectacles or any other special viewing device.

Attempts have already been made, on the lines indicated, to apply the stereoscopic effect to television, though, as might be expected, the subject is still very much in the experimental stage. It is, however, possible, even to-day, to produce the desired effect on the cinema screen, and what is possible one year may be commonplace the next, both in the cinema theatre and on the viewing-screen of a television set. Although we still require further technical advances, this does not mean that stereoscopic television will not finally arrive.

Stereophonic Broadcasting. At this point it may perhaps be of interest to refer briefly to the parallel problem of stereophonic sound which arises in ordinary broadcasting. When seated in a concert hall, sound reaches us from different angles. More particularly a given note or chord will take a slightly different path to the right ear from that by which it reaches the left ear. Obviously this means that there must be a small difference of phase in the sound wave picked up by the two ears.

Like the eyes the two ears are spaced apart in the head, and just as this separation gives rise to a stereoscopic effect in vision, so there is a stereophonic effect in sound which gives a definite impression of " depth " to what we hear. No one, for instance, can dispute the fact that music reproduced by a loudspeaker—or by a gramophone for the matter of that—sounds much " flatter " than when heard in a theatre or concert hall.

A CATHODE-RAY STEREOSCOPIC TRANSMITTER

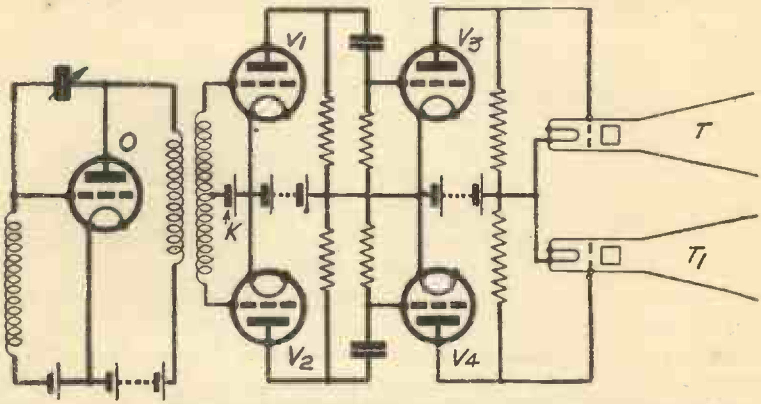


Fig. 204—Two cathode-ray tubes alternately scan the picture from slightly different angles in this interesting method

The production of stereophonic sound calls for much the same treatment as that already indicated for stereoscopic sight. In other words we must radiate two carrier waves, each fed by microphones which are spaced apart by the same distance as our ears, so that the two outgoing waves are modulated by sounds slightly out of phase with each other. At the receiving end, each carrier wave is separately rectified and fed to a pair of loud speakers, which then reproduce the sound with its true or natural effect of depth.

Whilst these are the ideal conditions for broadcasting sound, they are, of course, impracticable in the present over-crowded state of the ether.

BLOCKING VOLTAGES

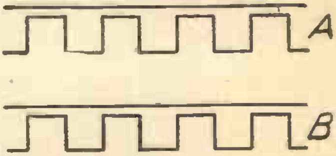


Fig. 205—Here you see a graphic representation of the cut-out voltages applied to the transmitter tubes T1 and T2

A Cathode-Ray System. In the Marconi system of stereoscopic television, two cathode-ray transmitters are arranged so that they view the picture to be televised from slightly different angles. The picture is scanned by each tube alternately; that is to say, the first scanning line is taken by the first tube, the second line by the second tube, the third line by tube No. 1, the fourth line by tube No. 2, and so on. Whilst one tube is scanning its own line, the other tube is cut out of action, and vice versa.

STEREOSCOPIC USE OF THE ICONOSCOPE

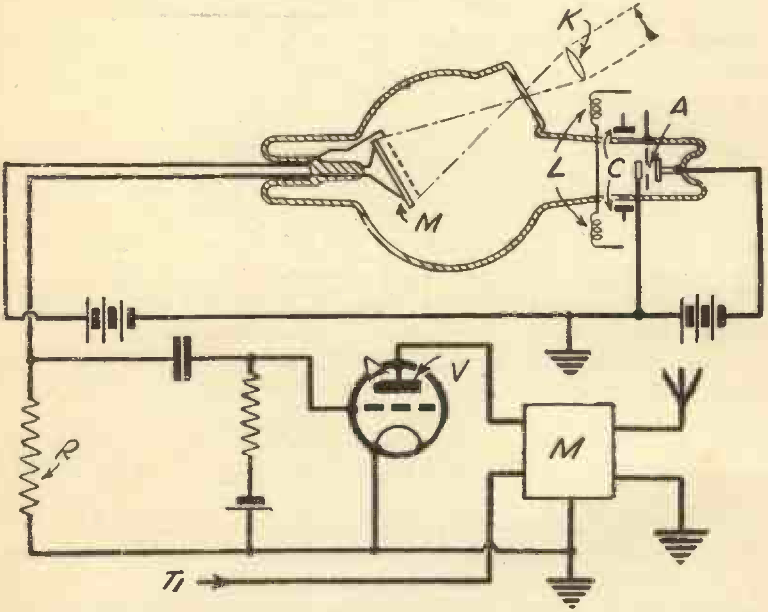


Fig. 206—Showing how a tube of the Iconoscope type is used in the Marconi Stereoscopic system

As shown in Fig. 204 the two cathode-ray tubes T, T1, are coupled through two pairs of push-pull amplifiers V1, V2, and V3, V4 to a generator valve O, the oscillations from which are amplified by the push-pull valves and applied to the control grids of the cathode-ray tubes in order to throw them periodically above and below "cut-off." As this is designed to make each cathode-ray tube effective only during alternate scanning lines, the generator valve O is, of course, tuned into step with the line-scanning frequency.

The grids of the first pair of valves V1, V2, are so biased at K that each valve only passes current during alternate half-cycles, and the shape of the blocking voltages applied to the cathode-ray tubes T, T1 is as shown at A and B in Fig. 205. These voltages it will be seen are in phase-opposition, so as to ensure " interleaved " scanning.

The cathode-ray transmitters are of the Iconoscope type, more fully described in another chapter. In this type of transmitter the scene to be televised is focused on to a photo-sensitive " mosaic " electrode, and is then scanned by the electron shown from the anode or " gun " part of the tube.

SCANNING VOLTAGES

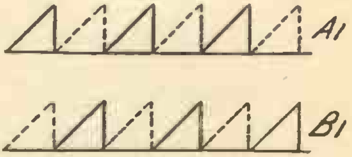


Fig. 207—The saw-toothed curves which ensure " interleaved " scanning

Fig. 206 shows one of the tubes in greater detail. The photo-sensitive electrode M is set at an angle to the main axis of the tube so that the view to be transmitted can be focused on to it through an outside lens K. As the rays of light from the lens strike against the electrode M, they set up electric charges on the " mosaic " surface of photo-electric cells. The distribution of these electric charges follows the varying light-and-shade values of the original pictures, so that the electrode as a whole acts in much the same way as a photographic plate, except that it produces an electric image instead of a chemical one.

Meanwhile the electron stream from the gun or anode A is being swept over the surface of the mosaic, in the usual scanning motion.

CATHODE-RAY STEREOSCOPIC RECEIVER

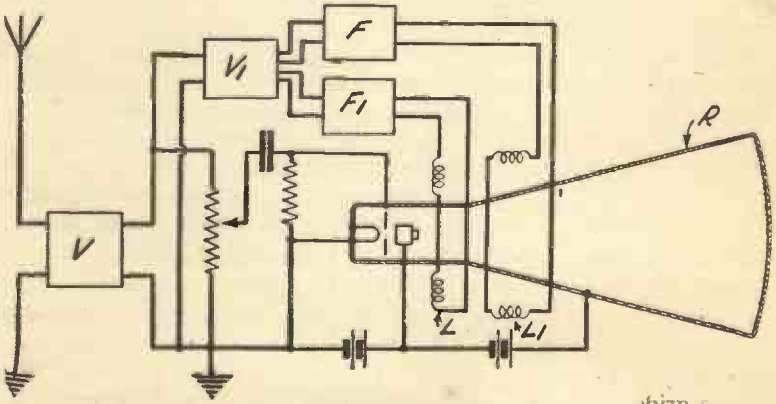


Fig. 208—A single cathode-ray tube is employed at the receiver

It will be noticed that the first or line-scanning frequency is applied from a pair of coils L, whilst the second and slower " frame " frequency is supplied by a pair of condenser plates C.

As the cathode ray passes over the mosaic electrode M, it " discharges " the electric image produced by the light rays from the lens K, and sends corresponding pulses of current through an output resistance R. These pulses of current constitute the picture signals. After being amplified at V they are fed through a modulator M to the transmitting aerial.

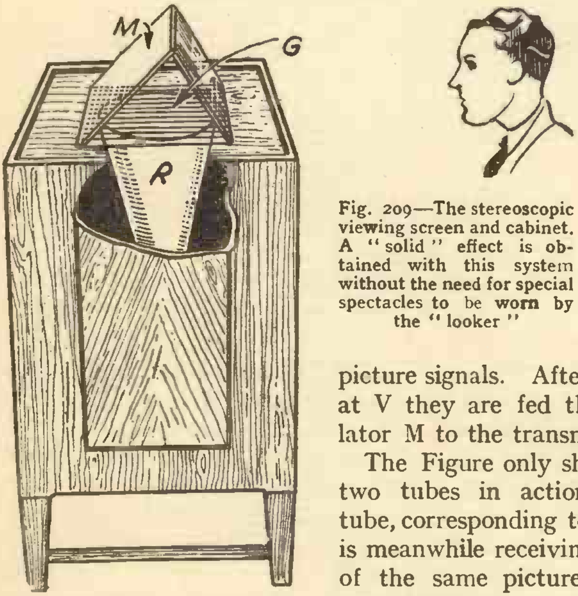


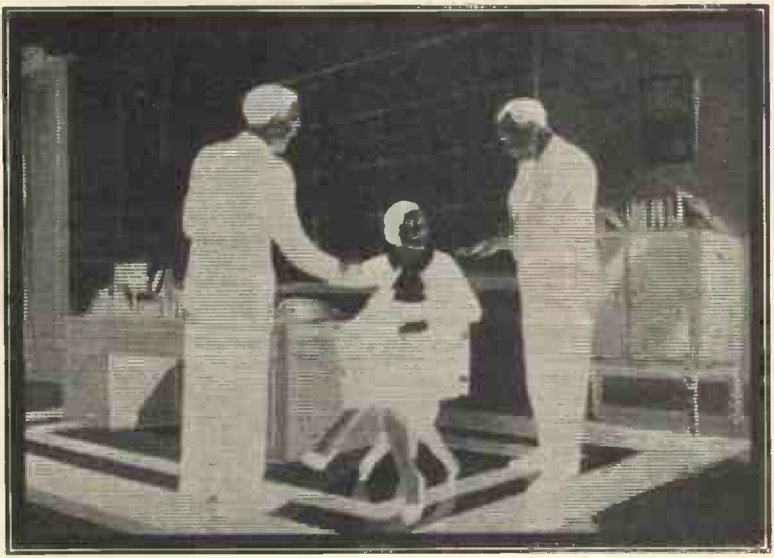
Fig. 209—The stereoscopic viewing screen and cabinet. A " solid " effect is obtained with this system without the need for special spectacles to be worn by the " looker "

The Figure only shows one of the two tubes in action. The second tube, corresponding to T1 in Fig. 208, is meanwhile receiving a similar view of the same picture from a second lens, which is, as already explained, slightly displaced from the lens K, in order to obtain the stereoscopic effect. The output from this second tube is similarly fed to the modulator M, and supplies its own quota of picture signals to the transmitting aerial.

But as already explained, the output from the two tubes must be " interleaved " so that a line of picture signals from one tube is followed by a line of picture signals from the second tube, and so on, in regular sequence. This is ensured by feeding the line-scanning voltages to the control electrodes L, C of the two tubes alternately, as indicated by the saw-toothed curves marked A1, B1, in Fig. 207. In both upper and lower curves only the full-line voltages are effective at any given moment. The dotted line or ineffective portions correspond, of course, to the " idle " periods produced in each cathode-ray tube by the blocking voltages A, B shown in Fig. 207.

At The Receiving End. The receiver is shown in Fig. 209. From what has already been said it is clear that the

HOW A "NEGATIVE" IMAGE WILL APPEAR



IF THE OUTPUT FROM THE RADIO VISION RECEIVER IS OF WRONG "POLARITY" A NEGATIVE PICTURE WILL APPEAR ON THE SCREEN AS ABOVE. THE CURE IN HIGH DEFINITION TELEVISION RECEPTION IS TO ADD AN L.F. STAGE OR TO CHANGE THE METHOD OF H.F. RECTIFICATION FROM AN ANODE BEND VALVE TO LEAKY-GRID OR VICE-VERSA

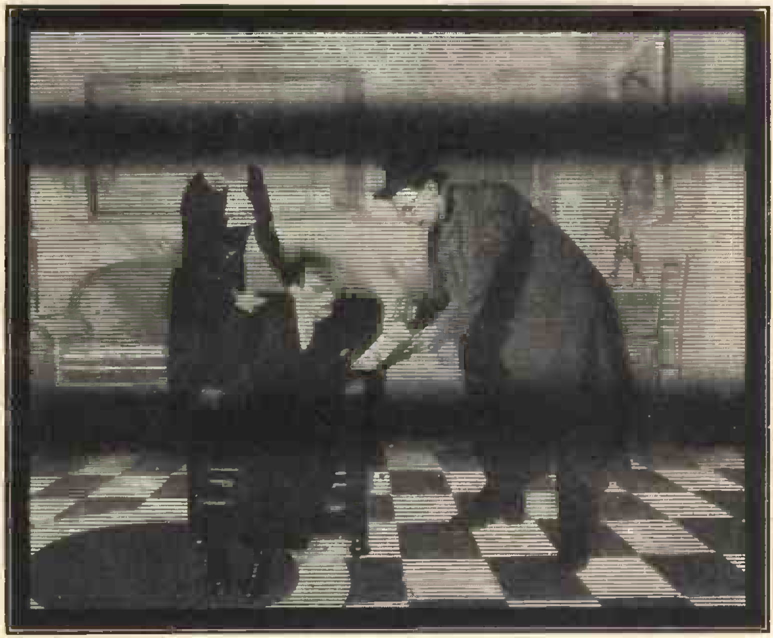
LACK OF "BASS"

THE EFFECT ON VERTICAL LINE SCANNING OF LACK OF BASS RESPONSE IN THE AMPLIFIER. THIS PHOTO ALSO SHOWS VERY CLEAR SCANNING LINES, DENOTING THAT THE CATHODE TUBE IS TOO HIGHLY FOCUSED

A.C. INTERFERENCE

BLACK BANDS ON THE PICTURE DENOTE A.C. INTERFERENCE. THE NUMBER OF BANDS VARIES WITH THE FREQUENCY OF THE A.C. SUPPLY AND THE SPEED OF THE PICTURE SCAN

RUINED BY A.C. RIPPLE

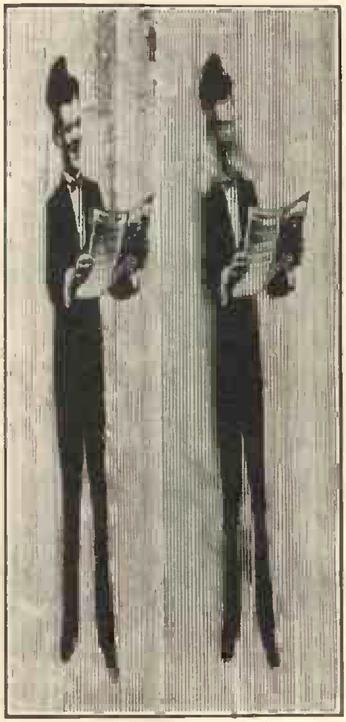


HERE WE SEE THE DISASTROUS EFFECT OF 50 CYCLE A.C. RIPPLE ON A 25 PICTURE-PER-SECOND SCANNING. IT IS USUALLY DUE TO INSUFFICIENT SMOOTHING IN THE TIME BASE

Plate 61

TWO COMMON FAULTS IN CATHODE-RAY RECEPTION

THE TOP PORTION OF THIS PHOTO SHOWS THE EFFECT OF EXTERNAL IRREGULAR INTERFERENCE. THE LOWER HALF SHOWS WHAT HAPPENS WHEN THERE IS "MISFIRING" OF THE SCANNING RELAY



BY RUNNING THE LINE-SCANNING CIRCUIT AT HALF SPEED YOU GET A DOUBLE IMAGE, LIKE THAT SHOWN HERE, RUN BOTH SCANNING CIRCUITS AT HALF SPEED AND FOUR SMALL PICTURES APPEAR incoming signals will consist of interleaved "lines" of picture elements, coming alternately first from one transmitter tube and then from the other. These are amplified at V and fed to the control grid of a single cathode-ray tube R. Meanwhile the synchronizing frequencies are tapped off to a second amplifier V1 and fed through filters F, F1 to the line-scanning and frame-scanning coils L, L1 in the usual way.

Now it is necessary to deal with the two sets of picture signals, so that, instead of being seen as one complete whole, the two "interleaved" series of scanning lines are in effect separated into two independent pictures, one to be viewed by the right eye alone and the other by the left eye alone.

SEPARATING THE TWO PICTURES

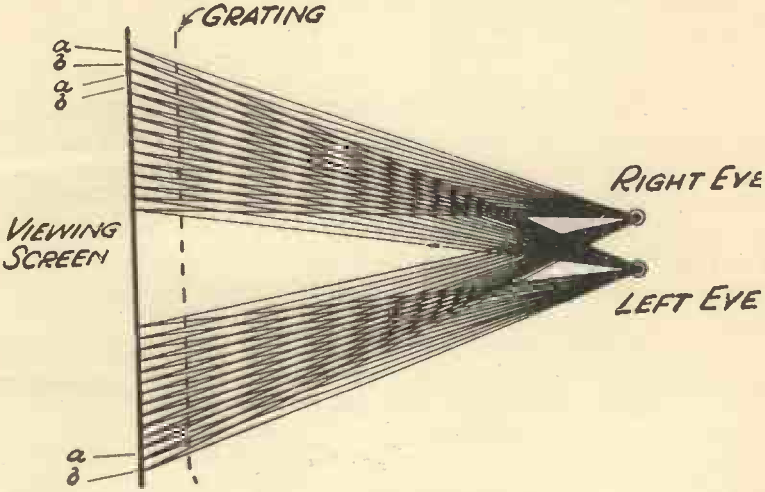


Fig. 210—The grating ensures that each eye sees only the lines of the picture appropriate to it

To do this the cathode-ray tube R is first mounted vertically in its cabinet as shown in Fig. 209, and a special adapter or grating G is placed just above the fluorescent screen. The grating consists of a series of opaque strips separated by transparent spaces of the same width, the number of strips and spaces being equal to the total number of scanning lines. The opaque strips of the grating G are arranged end on to the eyes of the observer, as shown in the Figure, and their effect is to mask one set of "interleaved" scanning-lines from say the right eye, whilst leaving that eye free to see the second set of scanning lines. J. C. J.

Chapter 24

TELEVISION IN COLOURS

"WHITE" LIGHT—THE PRIMARY COLOURS—COLOUR-SELECTIVE CELLS AND LAMPS—THE BELL TELEPHONE APPARATUS—SINGLE-DISC SYSTEMS—TELEVISING COLOURED FILM—SINGLE CHANNEL METHODS—COLOUR IN THE CATHODE-RAY TUBE.

All colour is derived from ordinary "white" sunlight which, as Newton showed, is really an intimate mixture of the seven colours of the rainbow, namely red, orange, yellow, green, blue, indigo, and violet. He proved this by passing a beam of white light through a glass prism, which bends or refracts short waves more than it does long waves. In other words, the prism acts as a filter which receives the different colours contained in white light and sorts them out into a spectrum with the shortest wavelength (violet) at one end and the longest (red) at the other. To make assurance doubly sure, Newton reversed the experiment and showed that the rainbow colours when mixed together in their proper proportions recombine to form white light.

A rose is red because it reflects from sunlight only the red waves and absorbs the others. Similarly, a ray of white light is not really stained—as the old philosophers thought—when it passes through a piece of coloured glass. The glass is simply transparent to one particular colour and not to the rest.

But the eye does not have to receive all seven of these colours. At least, not separately. It responds fundamentally only to red, green, and blue or violet, and builds up the remaining tints by mixing these in suitable proportions. The sensation of yellow, for instance, is produced by a mixture of red and green rays, purple by a mixture of red and blue, and so on for all colours outside the three primary ones.

The Primary Colours. When, therefore, we tackle the problem of printing or photographing things in their natural hue, we need only concern ourselves with the three primary colours, leaving the eye to fill in the gap and complete the full range. In three-colour printing, for instance, one negative is taken through a red filter, a second through a green, and a third through a blue. The same number of coloured inks are used when transferring the negatives to paper. The result may display all the tints of the rainbow.

The same principle underlies all systems of colour television, though there are various ways of applying it. In general, reliance is placed upon the colour-selectivity of the photo-electric cells at the transmitting end, whilst filters or special sources of coloured light are used at the receiver.

A PHOTO-CELL MYSTERY

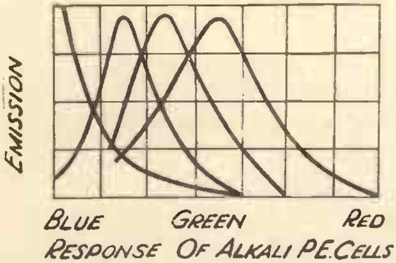


Fig. 211—The reason why different kinds of photo-cells respond differently to various colours is still something of a mystery

The fact that different kinds of photo-electric cells respond differentially to light of different colours is of great interest. Why exactly they should do so is still somewhat of a mystery, but Fig. 211, for instance, shows the selective colour-response of a group of cells in which the cathodes consist of the hydrides of different alkali metals. Fig. 212 shows the even more pronounced discrimination between blue and red light of cells containing specially-prepared films of potassium, caesium, and rubidium.

At the receiving end the primary colours are thrown on to the screen from suitable filters placed in front, either of a single source of " white " light (which, of course, covers the whole spectrum, or from two or more coloured sources, such as a Neon lamp for the red, and a mercury-helium glow lamp for the green and blue.

BLUE AND RED

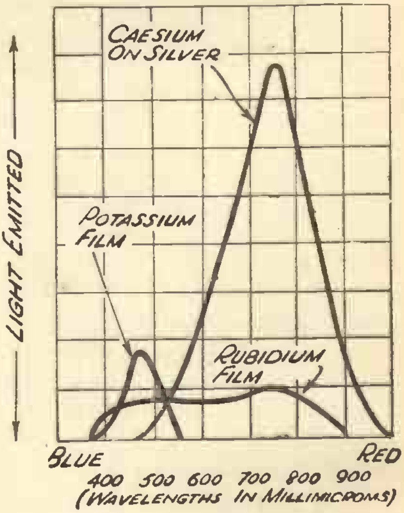


Fig. 212—Illustrating the pronounced discrimination between blue and red of certain types of cells

Colour-Selective Cells and Lamps. One of the pioneers in colour television is Jan Van Szczepanik, who as far back as 1897 designed an arrangement in which the object was scanned by two mirrors mounted to vibrate at right angles to each other. At the transmitting end the reflected rays were thrown on to a bank of light-sensitive cells, which responded selectively to the different natural colours concerned.

At the receiving end, the light from a lamp was first passed through a prism, thus producing a coloured spectrum, and control signals were then applied so as to ensure that at any given instant only the particular ray required to produce the natural colour of the object was allowed to pass through the scanning device on to the screen. This system is probably more ingenious than practical, but is quoted in order to show how early in the art attempts were made to secure the effect of natural colour.

TRANSMITTER USING A SINGLE DISC

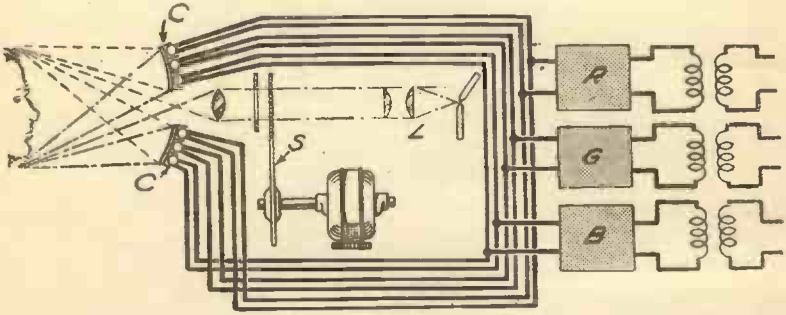


Fig. 213—Only one scanning disc and a single arc lamp figure in this ingenious colour television transmitter

The Bell Telephone Apparatus. Coming to more recent times we find the Bell Telephone Laboratories developing a system using three separate wavelengths, one for each of the primary colours, which would, of course, require more ether-space for broadcasting than is practicable under present conditions. Actually the scheme was intended to allow one person to see another in his or her natural colours whilst speaking over the telephone, and here, of course, the three different signals could be conveyed along as many separate lines; or they could be superimposed on different carrier-waves and fed into the same transmission line, say, for wired-wireless television.

With three channels it is possible to use a photo-electric cell which, instead of being selective to one particular colour, responds more or less equally to all three primary colours. One with a cathode of sodium treated with sulphur vapour and oxygen is found to give the required results.

As the modulators, amplifiers, and other intermediate parts used in colour television are in most cases identical with those employed in the standard systems already described in previous chapters, we can confine ourselves to the essential terminal apparatus.

Single-Disc Systems. As shown in Fig. 213, there is only one scanning disc S, and one arc-lamp L. The arrangement of the bank of photo-electric cells is shown in Fig. 214.

THE BANK OF CELLS

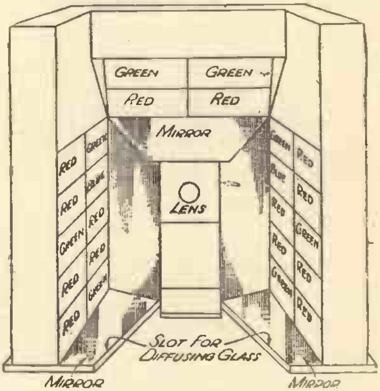


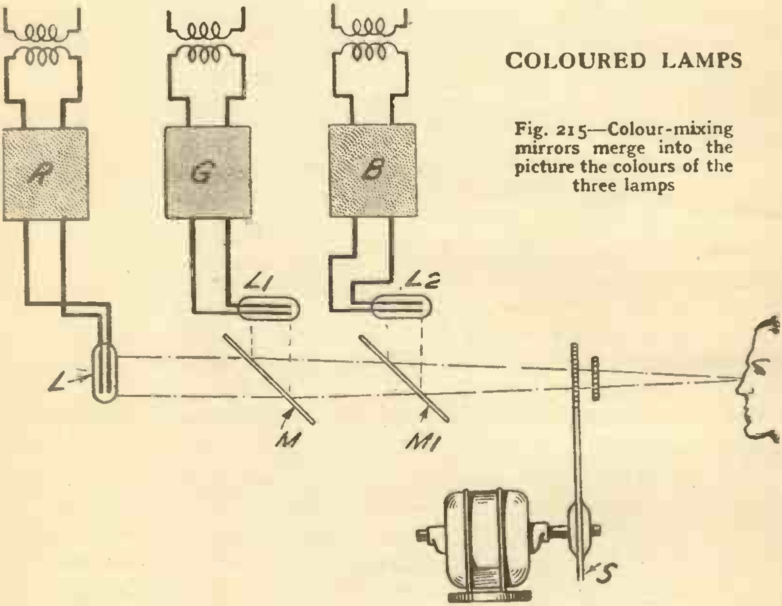
Fig. 214—How the bank of photo-electric cells is arranged

Although non-selective cells are used, each individual cell is covered by a red, green, or blue colour filter, so that it responds only to that particular component of the light as it is reflected back from the subject. But the total response of the red-filtered cells to the red component of the received light must be made equal to the total response of the blue-filtered cells to the blue light, and similarly for the green. It will, therefore, be seen in Fig. 215 that only two "blue" cells are used, these being far more sensitive than the others. Eight "green" cells are required, and no less than fourteen "red" to give a uniform overall colour response. The various cells are alternated or mixed with each other, as shown in the Figure, in order to avoid coloured "shadows" in the resulting picture.

As the subject is explored by the light from the lamp L through the scanning disc S, Fig. 213, the reflected light is thrown back on the bank of P.E. cells indicated in this Figure at C. All the red cells are coupled together and feed their combined output to the amplifier marked R. The green and blue cells are similarly bonded together and coupled to the amplifiers marked G and B respectively. From here the various currents are passed through modulators and further amplifiers (not shown) to three separate outgoing lines. Of course, colour filters need not be used if the photo-electric cells are of the kind which are inherently selective to the three primary colours.

At the receiving end the red, blue, and green signals are applied to three different glow-lamps, one of neon for the red, the second of argon fitted with a green filter, the third being also of argon, but fitted with a blue filter. Each lamp is controlled by a switch which automatically brings the three successively into operation.

Or instead of this arrangement the one shown in Fig. 215 may be used. Here the incoming signals are fed to the three amplifiers marked R, G, B which respectively energize the three coloured lamps L, L 1, L 2. The lamps are so arranged with respect to two semi-transparent mirrors M, M 1 that the light from each is combined and directed on to the single scanning disc, which is, of course, rotated at the same speed as the corresponding disc at the transmitting end.



COLOURED LAMPS

Fig. 215—Colour-mixing mirrors merge into the picture the colours of the three lamps

The light from all three lamps is thus swept in succession into the eye of an observer and there reproduces the object in its natural colours. Instead of being received directly by the eye, the reassembled colours may be first thrown on to a viewing screen in the ordinary way. Also it is possible to secure a very fair approximation to true colouration by using only two photo-electric cells, one for red, the other for green, together with two transmission lines, and the same number of lamps at the receiving end.

The schematic arrangement shown in Fig. 215 will perhaps be better understood from an inspection of Fig. 216 where the various lamps and mirrors are given corresponding reference letters. The semi-transparent mirrors M, M 1 are arranged at an angle of 45° to each other. The various lamps, it will be observed, are also fitted with colour filters to emphasize their natural tints and to cut out unwanted rays.

In operating the receiver, the first thing is to regulate the three lamps L, L 1, L 2 so that the combined light from all three appears white on the screen. This can be done either by selecting mirrors of different reflecting power, or by using colour filters of the required density. Signals are now transmitted, through the three channels, from a black-and-white object at the transmitter, and the strength of the received signals is then adjusted until the image shows up in pure black and white.

THE USE OF COLOUR-MIXING MIRRORS

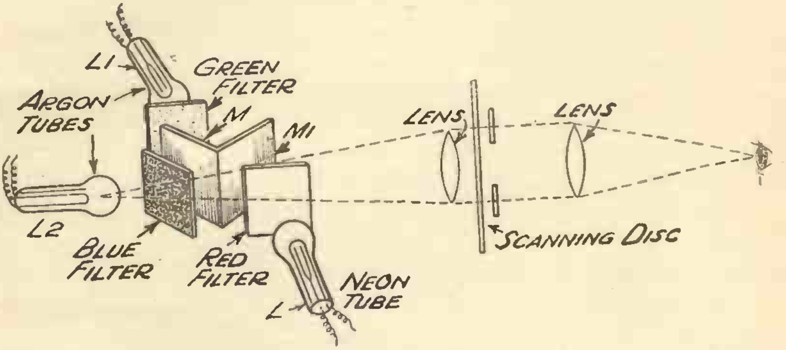
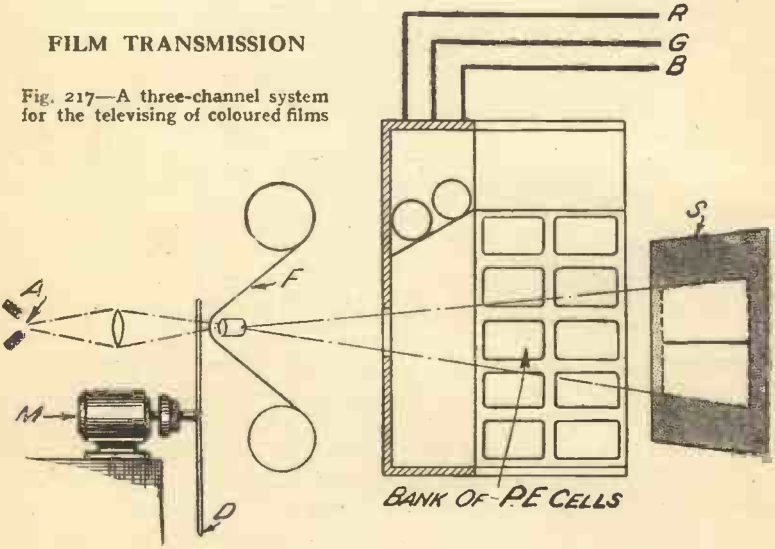


Fig. 216—Another view of the arrangement of the colour-mixing mirrors shown in Fig. 215

At this stage the black-and-white object at the transmitter is replaced by a coloured one, which should then appear correctly coloured at the receiver. If a single-coloured object is being transmitted, say a pure-red flower or an all-green apple, it is sometimes necessary, in addition, to adjust the direct-current controls at the receiver, in order to correct the "unbalance" caused by one set of P.E. cells being left completely out of action.

Televising Coloured Films. A similar three-channelled system has also been used for televising pictures from a coloured film. The apparatus at the transmitting end is shown in Fig. 217. The photo-electric cabinet contains, as before, three sets of colour-sensitive cells from which the red, green, and blue outputs are collected and passed through leads marked R, G, B respectively. Light from the arc-lamp A is focused upon the scanning disc D, which is driven by a motor M.

The light passing through the film F is first projected upon a dead-white screen S, from which it is reflected back on to the P.E. cells. If the scanning disc is rotated whilst the coloured film is held stationary, the screen S will receive a coloured image of the picture on the film, and the reflected light from this image is analyzed by the P.E. cells as in the system already described. In order to provide for the usual "intermittent" motion of the film through the gap, the scanning disc may be provided with a corresponding "blank" sector.



FILM TRANSMISSION

Fig. 217—A three-channel system for the televising of coloured films

Or the disc may be fitted with a uniform spiral of holes, and the film so driven that it moves constantly and uniformly past the scanning point.

Single-Channel Methods. In the Baird system of three-colour television, only a single channel is used for transmitting the signals, so that it possesses an immediate advantage in this respect. On the other hand it is necessary to use either three separate scanning discs, or a single disc provided with three distinct sets of spiral apertures, as shown in Fig. 218. One set of apertures is covered by a red gelatine filter, the second with a green filter, and the third with a blue.

As before the object to be televised is surrounded by a set of photo-sensitive cells, preferably of the colour-selective type, and as the scanning disc rotates it is swept in swift succession by a ray first of red, then green, and then blue light, followed by red again, and so on. During the red traversal only those parts of the object which are naturally red reflect any considerable amount of light on to the P.E. cells. The other parts of the picture absorb this colour, and so reflect nothing. During the green traversal the green parts similarly contribute their quota of light to the P.E. cells, whilst the parts that are otherwise coloured remain "dead." The same applies during the blue traversal.

A BAIRD METHOD

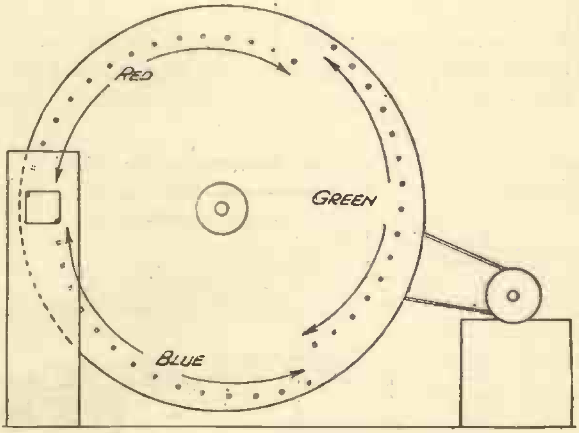


Fig. 218—The disc employed for a single-channel three-colour arrangement due to Baird

The result is that three separate sequence of signals are sent out into the ether, the first containing only the red, the second the green, and the third the blue "lights." These arrive in the same order, and in rapid succession, at the receiver, where they are handled by the apparatus shown in Fig. 219.

The scanning disc contains the same number of spiral holes and is driven at the same speed as the one at the transmitter, the three sets of spirals being similarly fitted with red, green, and blue filters respectively. Two light sources are used, one a neon lamp which provides the red light, whilst the other is a mercury-helium lamp. The latter gives a mixture of green and blue rays which are separated out by green and blue colour filters.

An important item is the commutator switch, which is so arranged that the neon lamp is lit only when the red batch of signals are being received. During the arrival of the green and blue signals, the neon lamp is extinguished and the helium lamp is alone in operation.

The result is that as the red spirals on the disc pass the eye of the observer, the red batch of incoming signals are modulating the intensity of the neon lamp and reproducing the red elements of the complete picture. The green and blue components are similarly brought into play in quick succession, as the corresponding parts of the scanning disc in turn pass the observer's eye.

The sequence of events is so rapid that the eye automatically merges the three successive presentations into one complete whole, in which the various parts of the picture show up in their natural colours.

Although it might be thought that the scanning speed ought to be increased to three times that ordinarily used, in order to prevent flicker, this is not so in actual practice. The eye retains a coloured picture even longer than it does an ordinary black and white one, so that the persistence-of-vision effect comes into play to tolerate a lower speed of projection on to the screen.

SINGLE-CHANNEL RECEPTION

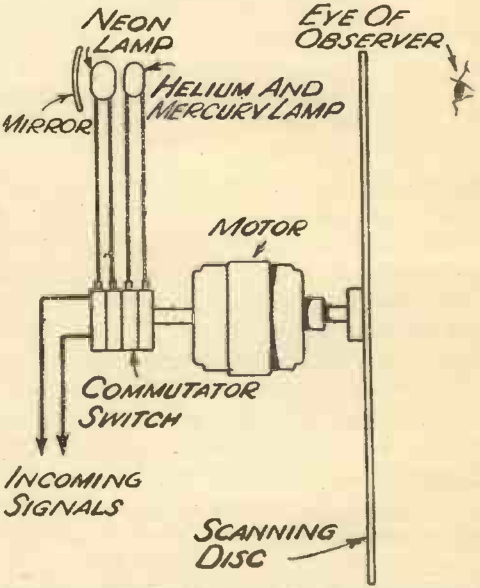


Fig. 219—There are only two lamps, the neon provides red light, and the mercury-helium both green and blue, filters being used to separate them

Colour in the Cathode-Ray Tube. Coloured effects can also be obtained in cathode-ray television. In one such system a three-colour screen, of the kind used in colour photography, is arranged between the object and the cathode-ray tube at the transmitter, and a similar screen is placed between the observer and the fluorescent screen at the receiver.

Another plan is to make the screen itself of a mixture of fluorescent materials, each of which produces one of the three primary colours. It is necessary, of course, to scan the screen separately for each colour.

J. C. J.

Chapter 25

BROADCASTING TALKIE FILMS

ADVANTAGES OVER DIRECT TELEVISING—SCANNING THE FILM—AN EARLY METHOD—THE MIRROR DRUM—DISC SCANNING — CURVATURE DISTORTION — METHODS OF SYNCHRONISATION — PHOTOGRAPHING SOUND — LINKING PICTURES AND SOUND—THE SOUND TRACK—THE DIFFERENT METHODS—DESCRIPTION OF THE OPTICAL SYSTEM—TYPICAL "SOUND HEADS"—THE PHOTOCELL CIRCUIT.

It is a much simpler process to televise a film than it is to televise original scenes. As we have seen in an earlier chapter in this book, the main difference between the two is that in the one case there is only reflected light, while with a film, concentrated direct lighting can be employed.

A television transmitter has to bow to the same limitations as does the human eye when viewing a scene. The camera does, too, but this is able to accept the whole picture at once. In television it is necessary to deal with the picture point by point in successive tiny spots.

The amount of light which is reflected from, say, a piece of a man's coat, or wall, or anything else, maybe smaller than a pin's head, is diminutive to the extreme even when there is full sunshine illuminating it.

But that is all the light that a television transmitter gets when it has to handle original scenes.

With a film hundreds, if not thousands, of times more light can be conveyed to the photo-electric cell which transforms the light variations into fluctuations of electrical current.

A film can be a practically perfect light valve. If it is black all over because, perhaps, it is necessary to convey the impression of a completely dark room, then it will allow no light at all to pass. At the other extreme the photo of a cloudless sky would appear as almost clear celluloid and there would be hardly any opposition at all to light passing through it.

So it is clear that the amount of light available in film television is limited only to the amount which can be developed and concentrated in a thin scanning beam.

Generally an arc lamp is employed for the reason that it gives an extremely intense concentrated illumination. This light is focused on to a scanning device which allows a pin point of it to go through, and it is then passed to the film via another lens.

The density of the film varies from spot to spot, and so it is a varying light intensity which ultimately reaches the photo-electric cell.

That in broad outline is what happens in the picture-transmitting section of a film television apparatus. But now let us consider in detail how the picture is " broken up."

Scanning the Film. The moving film itself supplies scanning in a vertical direction. It is moving steadily downwards all the time as it unrolls from the one reel, passes through the " picture head," and so to the " sound head"

This movement is, of course, created by means of a smooth-running electric motor which operates sprockets that fit in the perforations at the sides of the film.

FILM PICTURE ANALYSIS

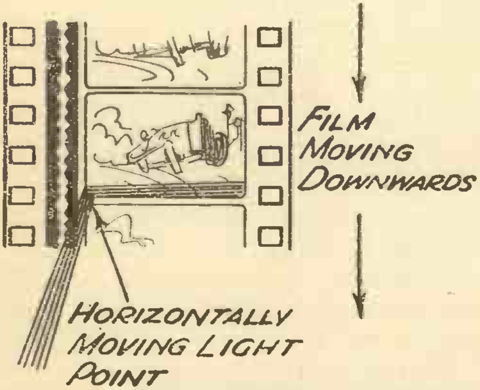


Fig. 220—The film moves smoothly downwards so that the light scanning is necessary only in a horizontal direction

Twenty-five complete pictures pass a given point in each second. Which is the same thing as saying that one complete picture goes through the " picture head " (and the " sound head," too) in a twenty-fifth of a second.

With the picture moving downwards at a uniform speed in this way it is obviously necessary only to sweep a light-point across horizontally in order to obtain complete scanning (Fig. 220).

One of the illustrations shows the principle of this. A point of light is focused on the film so that it shines on the bottom left-hand corner of the picture. If this point is swept to the right at the same time as the film is moved downwards a fraction, there will be a slightly sloping track of light across the picture—sloping upwards it should be noticed.

If the film is kept moving and the light-point very rapidly snapped back it will arrive at a point slightly higher than where it started from in the first place. A further horizontal movement with the film still moving enables the light-point to cover another fractional strip of the picture just above the first one.

By repeating the process of simply moving the light-point horizontally while the film is steadily moving, the whole area can be covered.

An Early Method. One of the earliest methods of obtaining the moving light-point was by means of a small mirror which was made to rock to and fro at the desired speed (Fig. 221). This was quite satisfactory for the low-definition systems. These necessitated the picture being broken up into only 30 or so strips. With even 25 pictures per second that meant that the mirror had to vibrate a mere 750 times per second. But with 240 line scanning and 25 pictures per second the mirror would have to vibrate at a 6000 per second rate.

THE OSCILLATING MIRROR

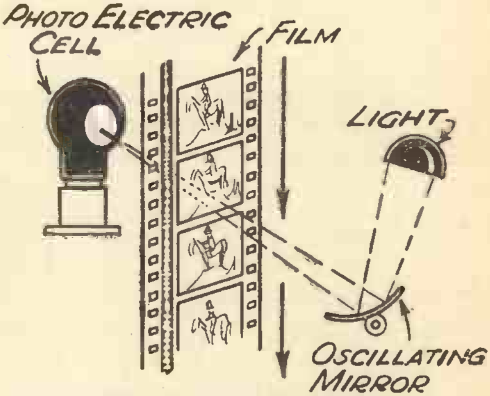


Fig. 221—In this early method of film scanning the light-point was made to move in a horizontal plane by means of a small rocking mirror

This might still be possible, but the idea is not practical for the reason that an evenly oscillating light-point is unsuitable. It might be practicable to arrange for a tiny mirror to sweep a light-point from one side of the picture to the other and snap back to the starting side at a proportionately much greater rate if it had to do this only a few hundreds of times per second. But it could not do that 6000 times per second. All that could be hoped for at that rate would be an " oscillation " where the movement to the one side would be approximately at the same speed as on the return journeys.

The Mirror Drum. Fortunately other methods were discovered. There are two in general use to-day, the mirror drum and the disc. The mirror drum is a device like a broad-rimmed wheel around the rim of which is arranged a number of mirrors. An intense light is focused on one point of the rim and as each mirror reaches this so, as the wheel rotates, it sweeps a light-point across the film picture. All the mirrors reflect their light-points along the one plane (at the same level). Remember it is the downwards movement of the film itself which causes each successive sweep to be a little higher up in the picture. That is what we meant when we said that the film supplied the vertical scanning. Therefore, the mirror drum scanner for films is a simpler device than the mirror drum used in receiving apparatus.

The receiving mirror drum has to have its mirrors tilted at different angles, each one giving a light-point sweep a little higher than its predecessor.

Disc Scanning. The same greater simplicity is to be seen in the disc type of film scanner (Fig. 223). In this the holes do not require to be spiralled as in the disc scanners used in receiving equipment.

The equally spaced holes are arranged in a circular formation. Each hole is separated from its neighbours by a distance representing the width of the picture. With the disc rotating so that its holes pass across the film pictures, a steady and intense illumination is transformed into a series of light sweeps (Fig. 222).

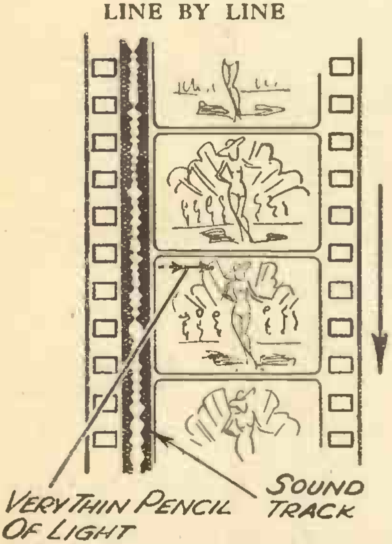


Fig. 222—Each picture is traversed by the light-point in a succession of thin lines

In one system the scanning disc is made to rotate twice for every picture. Therefore, in each single revolution it deals with half a picture. The purpose of this is so that there need be only half the holes in the disc. For 240 line scanning there still have to be 120, and that is quite enough!

If it is remembered that the holes have to be spaced to the extent of the width of the film picture it will be appreciated that the number of holes governs the size of the disc. The width of pictures in normal standard film is some threequarters of an inch or so. Therefore, a disc with 120 holes for 240 line scanning must have a diameter of more than 2½ feet.

It might be thought that by decreasing the number of holes still further the same definition could be preserved with a proportionately smaller disc rotating at a higher speed. But there are limitations.

As we have said a 120 hole disc revolving twice per picture is usually employed for 240 line scanning. Now there are twenty-five pictures per second. That means the disc must rotate at a rate of 50 times per second. That is three thousand revolutions per minute, to use familiar engineering language.

For higher speeds it is necessary to adopt special measures. Thus in Germany 300 line scanning is achieved with discs rotating in vacua at speeds up to 6000 revs per minute.

But it is not desirable to have a very small disc with few holes for a reason that is not connected at all with speed of rotation.

For ideal horizontal scanning the light-point should move across the picture in a straight line.

A MODERN METHOD

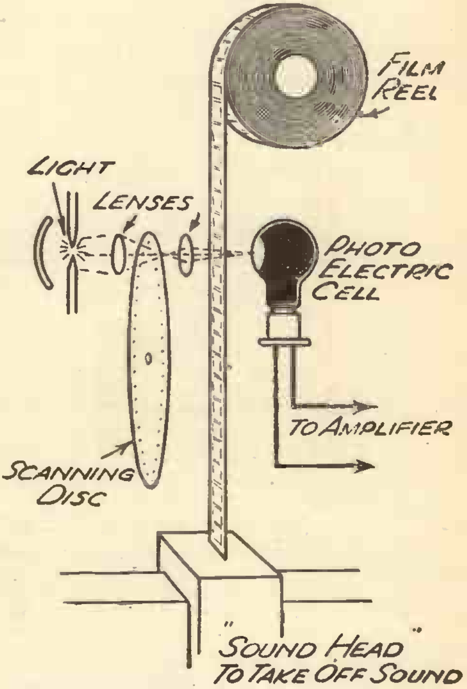


Fig. 223—A simplified illustration of the modern disc method of film scanning

Curvature Distortion. With a disc scanner the light-spot is bound to follow a curved course, and the curve becomes more pronounced the smaller the disc is made. If the receiving scanning were by means of a similar disc that would afford correction, but if, as much more likely to be the case, a cathode-ray scanner is employed at the receiving end the picture is distorted.

This distortion is so slight as to be quite unnoticeable when the 240 line two-revolutions-per-picture scanning disc figures in the transmitter. But with a smaller, faster-rotating disc it might become very marked indeed.

It is interesting to note that the curvature of the picture is exactly opposite at the receiving end. This can easily be explained. Supposing the transmission were to employ a small disc giving exaggerated curvature distortion. At the receiving end there might be a cathode-ray outfit. Now the cathode-ray tube does give straight line scanning, the straight lines being tilted very slightly, although this is a quite unnoticeable effect.

While the light-spot was sweeping the film at the transmitter it would follow a series of arcs. Let us take one line. It starts at a certain point to the one side of the picture and first sweeps upwards to some extent, as well as sideways.

The higher points in the picture it reached would be brought down lower at the receiving end because the receiving scanning spot is not following the same arc but is preserving a virtually straight line. At least, it ought to be though in many instances it will be found that there will be curvature distortion due to other causes inherent in the reception apparatus (Fig. 224).

EFFECT OF CURVATURE DISTORTION

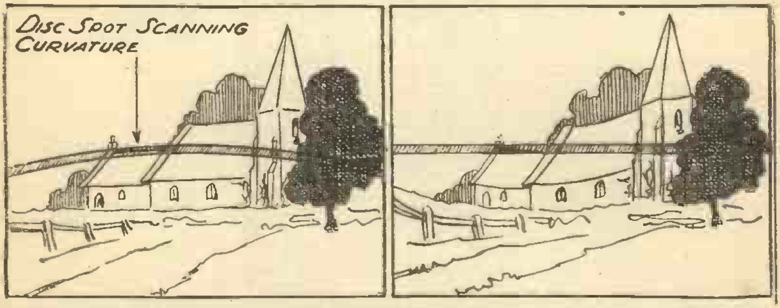


Fig. 224—On the left is shown the track of a light-spot across the picture to be transmitted which is following a curve instead of the ideal straight course. On the right is depicted the effect caused at the receiving end. Here the scanning is in straight lines, but nevertheless the picture is distorted

But this is not likely to interfere to any appreciable extent with the enjoyment of the picture. When it is present at all it will mostly miss the attention of all but the expert and critical " looker."

Methods of Synchronisation. There is still another important aspect of the televising of films with which we must deal, and that is the synchronisation. It is not enough to send the electrical equivalents of a string of light spots through the ether. There must also be a synchronising signal to enable the receiver to keep exactly in step so that as the transmitter analyses the picture so in synchronism the receiver can build it up.

The Baird system ingeniously uses the black borders which are to be found surrounding a film picture. The light-spot is extended in its travel so that it takes in the side border at the end of each of its horizontal sweeps. For each line in the scanning operation there will be a momentary period of " no light at all." This produces a six thousand per second frequency in 240 line, 25 picture transmission which can be used at the receiving end for synchronising purposes in the manner which has been described elsewhere in this book.

An E.M.I. method introduces an independent synchronising signal, independent of the picture and its light-spot, though naturally of a correctly corresponding frequency. This frequency is embodied in the transmission at a greater depth of modulation. That is to say, it is a much stronger signal than are any of the impulses connected with the picture. This makes it a fairly simple matter to render the synchronisation distinct from the picture frequencies at the receiver. To put it another way, none of the electrical impulses used for building up the picture can be as strong as the synchronising impulse, however great are the contrasts of light and shade in the picture.

Our detailed examination of the processes concerned with the televising of talkies must surely have brought one outstanding fact into prominence, and that is, that the whole business is a purely electro-mechanical operation. Once the apparatus is initially adjusted the human element plays practically no part at all. Any length of film can be fed into the machine, and it can then be left to carry on for just as long a period as required, with only one or two engineers present for maintenance purposes. Indeed, there are few, if any, greater difficulties than are met with in the running of an ordinary projection installation in a cinema.

From the point of view of broadcasting engineers therefore, televising talkies is an extremely attractive proposition. G.V.D.

* * * * *

Photographing Sound. The type of film which we have come to know as a " talking film " is a cinematograph film which carries a photographic record not only of the pictorial scenes but also the sounds which accompany them. This includes films made in the large film studios, with famous stars in the lead, as well as news films taken here, there and everywhere.

It also includes a new scheme which has come to the fore in connection with television, and that is the method of televising a broadcast studio show or a news item, within a few seconds of its performance by first making a " talking film " of the performance and then immediately televising it. The reasons for doing this, instead of televising it directly, are explained elsewhere in this book.

Now when any pictorial scenes are transmitted by television through the ether to our homes the scenes themselves are sent on one wavelength, usually a very short one for high definition, for example, Berlin is using 6.9 metres, and the sounds which accompany those scenes are sent on another wavelength, and it is not very important what wavelength is chosen since the only requirements are those at present existing for normal broadcasting of sound.

There is one very important point which must not be overlooked and that is the absolute necessity that the sounds exactly accompany the scenes. There must not be any delay nor lack of synchronisation between the pictures and the sound.

Linking Pictures and Sound. The reason for emphasizing this point is to make it quite clear that when a scene is televised through the intermediary of a cinematograph film it is quite impossible to transmit the sound direct from the microphone as at present with simple sound broadcasts. It is true that the best results appear to be promised by the method in which the scene is first photographed on to a cinematograph film, since this lends itself much better to the scanning systems than does the original scene but it is not possible to process a film in no time at all.

Hence it will be appreciated that although such a film can be processed and scanned within about twenty seconds of taking the scene, such a delay, even if it were much less, means that the sound also must be recorded and transmitted afterwards in synchronisation with the pictures.

The Sound Track. Since it is intended to use the intermediate film method almost always and only rarely to televise the scene direct through the high definition service, it is very interesting to see just how the sound-via-film will be done.

In order to understand just how the sound is transmitted from the film to your houses, it is necessary to know the form in which it is recorded on the film, so that we must briefly review the way in which the recording is done.

In the first place the sound is usually recorded along one edge of the film at the side of the pictures, as seen in the sketches. The width of the sound track is one tenth of an inch. The film is 35 millimetres wide overall, and there are 25 pictures a second on television talking films. Each picture in the film is ¾ in. high so that 25 pictures, that is one second's showing, require a length of 18¾ in. of film.

This then is the rate at which the film moves past the gate where the sound is recorded on it and likewise it will have to move at the same rate through the gate where the sound is taken from it for transmitting. If a standard talking film of 24 pictures a second recording (as used in cinemas) is transmitted in the same apparatus, and certainly television will have to be constant at 25 pictures a second, the difference in the animation of the scenes will be barely perceptible while the pitch of the sounds will all be raised 4 per cent, which is very little.

HOW SOUND IS "PHOTOGRAPHED"

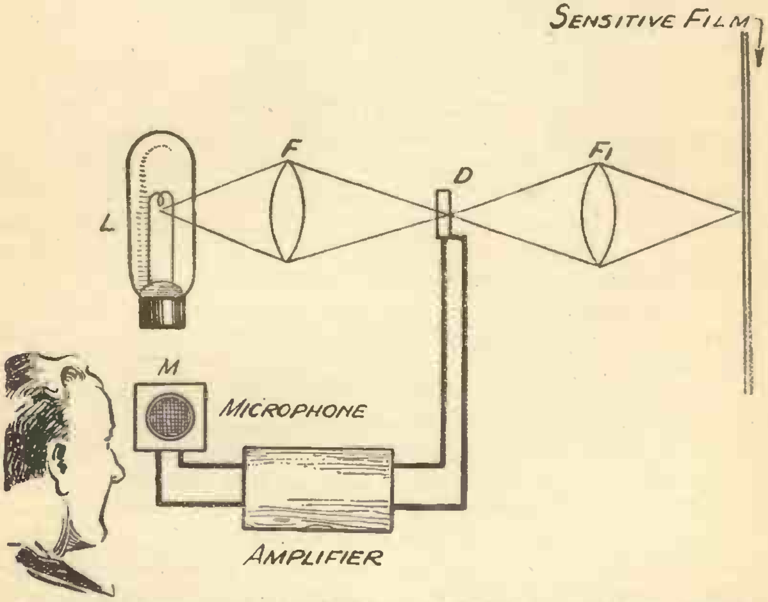


Fig. 225—The fundamental principle behind practically all methods of recording sound on films

If you want to see just what this difference means, play a gramophone record first at the correct speed of 78 and then at 81, and the latter will be as near as possible the pitch at which a standard talking film will have to be transmitted on the new 25 picture per second television system.

The Different Methods. All sound which is recorded on film is done so in a very simple manner. Different methods vary in minor details, but the principle is illustrated in Fig. 225, where L is a powerful light, which is focused by the lenses F and F^1 on to the film, which is moving smoothly in the direction shown by the arrow.

The sounds from the microphone M pass through the amplifier and control a device D in the path of the light. This device can take one of several forms, but they all function merely by controlling the amount of the light passing through F^1 on to the film in accordance with the signals coming from the sound amplifier and microphone. Fig. 226 (a) and (b) show the results obtained with two common methods.

THE "SOUND TRACK"

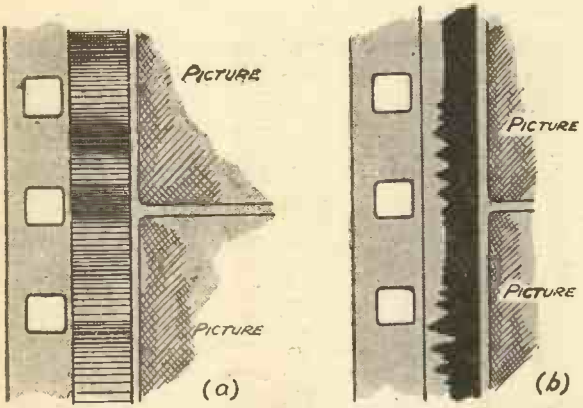


Fig. 226—At (a) is shown the appearance of a sound track recorded on a film by the "variable density" method. (B) illustrates a simple "variable area" recording

Such a simple method suffers from "background noise," which in the case of Fig. 227 (b) is due to dirt and photographic specks on the transparent part of the film. This is overcome by incorporating a further device in the recording system to block out the greater part of the clear area, giving the recording of the type shown in Fig. 227 (a). A further modification of this is shown in Fig. 227 (b). Another method to obtain the same noiseless recording is shown by the sound track in Fig. 227 (c).

Description of the Optical System. It is very fortunate that no matter what system is employed for recording the sound, the films can all be used in the same apparatus for reproducing the sound without requiring any change at all. The method for doing this is in principle very simple. Fig. 228 (a) shows the essential elements of the optical system.

Again there is a source of light X, which is focused on to the film by the lens f and f^1. Between these lenses there is a mask with a slit in it, this slit being .0015 in. wide, and about .18 in. long. This is focused by the lens f^1 down to a width of .001 in. wide and further masked down to a length of .08 in. on the sound track of the film. In Fig. 228 (b) this can be seen in perspective view.

The sound track itself is .1 in. wide, so that the slightly shorter length of the light image (.08 in.) on this allows for slight unevennesses at the edge of the sound track since these are not used. The position of the light and the lenses must, of course, be accurately adjusted to ensure satisfactory working.

In Fig. 228 (c) there is shown a very interesting modification of the optical system whereby the ordinary lenses f and f^1 are replaced by two cylindrical lenses. One of these cylindrical lenses focuses the light image down in one direction, while the other cylindrical lens focuses it down in the other direction.

CUTTING OUT NOISES

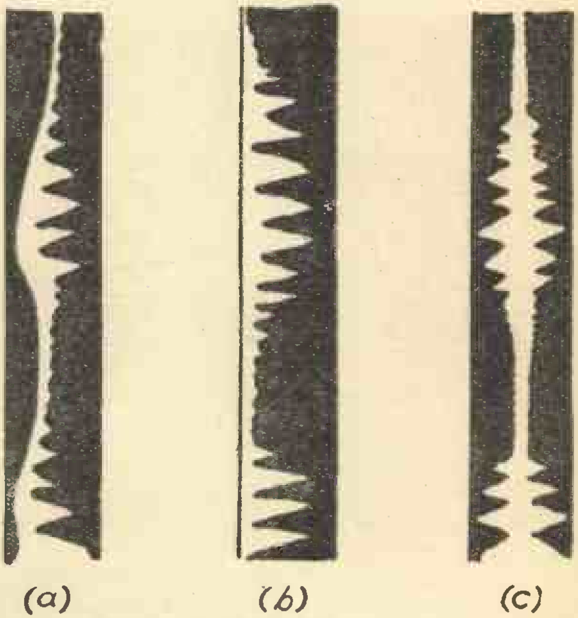


Fig. 227—Methods of reducing the clear areas of a sound track in order to reduce background noises due to dirt and photographic specks on the transparent areas

This method has the advantage that it needs no mask with a slit, since the two cylindrical lenses are able to reduce the size of the image with full efficiency, and gives at the same time a much sharper image. Not only is the width of the beam reduced to .0001 in. which is one-tenth of the width given by the " slit " method, but moreover the whole of the light is used, which normally means three or four times greater brilliance with, of course, this increase in the sensitivity of the system.

Typical " Sound Heads." It will be seen that as the film moves in the direction shown by the arrow the amount of light transmitted by the sound track will fluctuate in accordance with the sound record on the film. This fluctuating transmitted light falls on to a photo-electric cell, often called simply a photocell.

The general layout of the parts known as the sound head can be seen in Fig. 229, where the light source L is seen on the left in its housing, and the photocell is on the right. The film is travelling downwards and comes from the television scanning apparatus situated above, of which only the photocell is shown.

TALKIE TRANSMITTER OPTICS

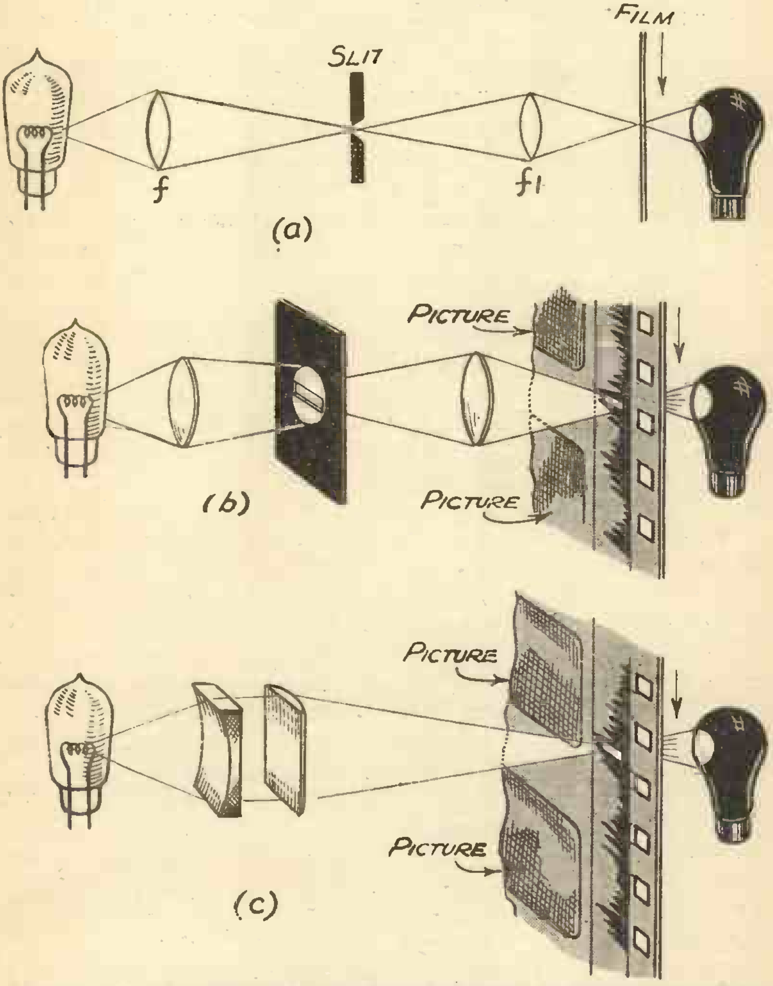


Fig. 228—The upper illustrations show the optical system in diagrammatic and perspective forms. At C is depicted an interesting modification, in which cylindrical lenses are employed which render the use of a mask and slit unnecessary

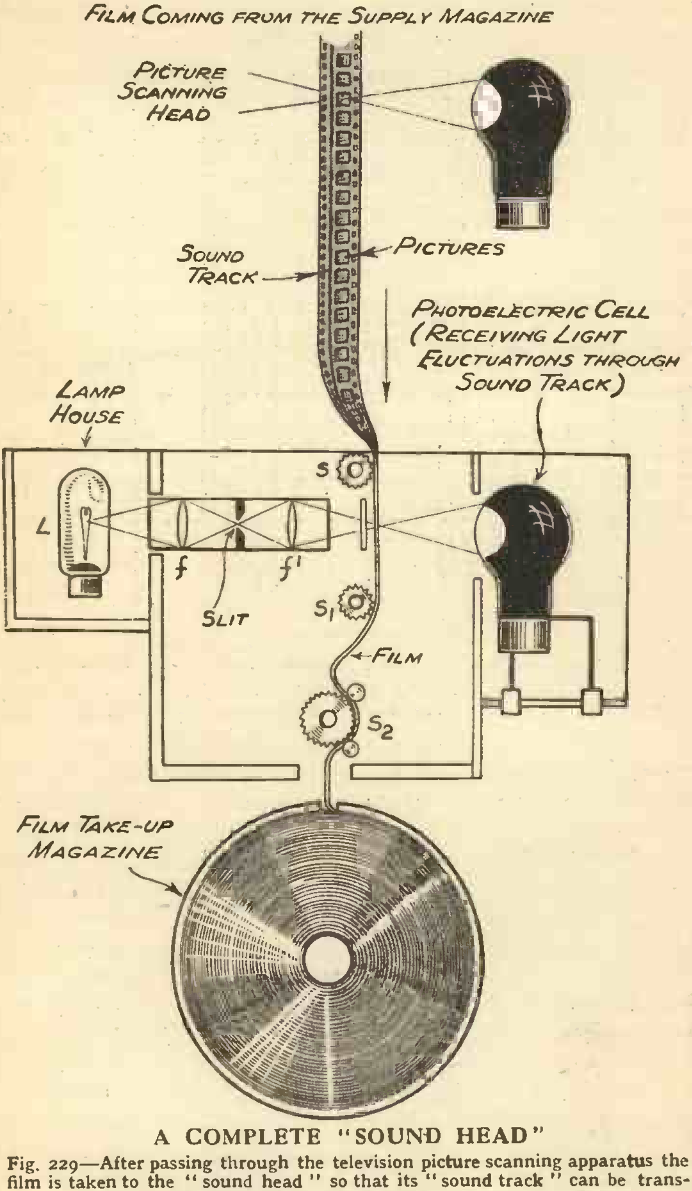
In cinema projectors the film moves intermittently through the picture gate, but smoothly in the sound-head. In television it is a great advantage that the film moves smoothly in both places, which conduces to very sweet running, and accurate results.

Where the film enters the sound head it runs over two sprockets S and S^1 between which the light passes through the sound track. It will be noticed that when this light beam is "reproducing" the sound at one point on the film the picture scanner above has already scanned and broadcast the pictorial scene. On the face of it therefore there is a "delay" which we previously said must be avoided. Actually, the amount of film between the sound gate and picture gate has been standardised at 14½ inches. Accordingly in all talking films the sound is recorded this amount ahead of the pictures on the film, hence in the reproducer they are then exactly in synchronism.

The speed of the sprocket S^1 is very carefully governed because it is essential that the film moves past the light beam at a perfectly constant speed. The film passes over a third sprocket S^2 before it enters the take-up magazine, this sprocket being known as the hold-back sprocket. The film is arranged to form a loop between S^1 and S^2 thereby avoiding any jerkiness. Any variations in the speed of the film as it passes the light beam become very apparent as a whine just as when a gramophone motor is running with a periodic variation.

In fact, the whole system can be very conveniently likened to a gramophone, and such analogy enables its functioning to be very easily understood. Clearly the film is equivalent to the gramophone disc since it carries the record. Next we have the light beam which "bears" on the film just as the gramophone needle bears on the disc. Then just as the gramophone needle, by its vibratory movement sets up electrical fluctuations in the coil of the pick-up, so the light beam sets up electrical fluctuations in the potential across the photocell. Hence it is immediately obvious that the photocell is connected into the subsequent amplifying circuit on the same principle as a gramophone pick-up. There is a minor difference due to the fact that the photocell requires to be supplied with an external source of steady potential.

The Photocell Circuit. You will see how the photocell circuit is connected to the first valve in Fig. 231. If the resistance R is neglected for a moment we see that we could simply replace the photocell by a pick-up and have quite a normal pick-up circuit. The condenser C is, of course, essential with the photocell when the resistance R is in position. Through this resistance R the high tension voltage (also known as polarizing voltage) is supplied to



A COMPLETE "SOUND HEAD"

Fig. 229—After passing through the television picture scanning apparatus the film is taken to the "sound head" so that its "sound track" can be transformed into electrical impulses suitable for broadcasting

the anode of the photocell. In the case of the Osram CMG 8 photocell the resistance has a value of 500,000 ohms.

The Osram CMG 8 is much more sensitive than the older type cells in which the cathode was potassium. In the new cell the cathode is caesium on a silver oxide undercoating, while the bulb is filled with argon gas. When light falls on the cathode, the shape of which is a vee-shaped plate, current flows to the anode, this current being proportional to the amount of the light.

It is very small, being measured in micro-amperes.

L. E. T. B.

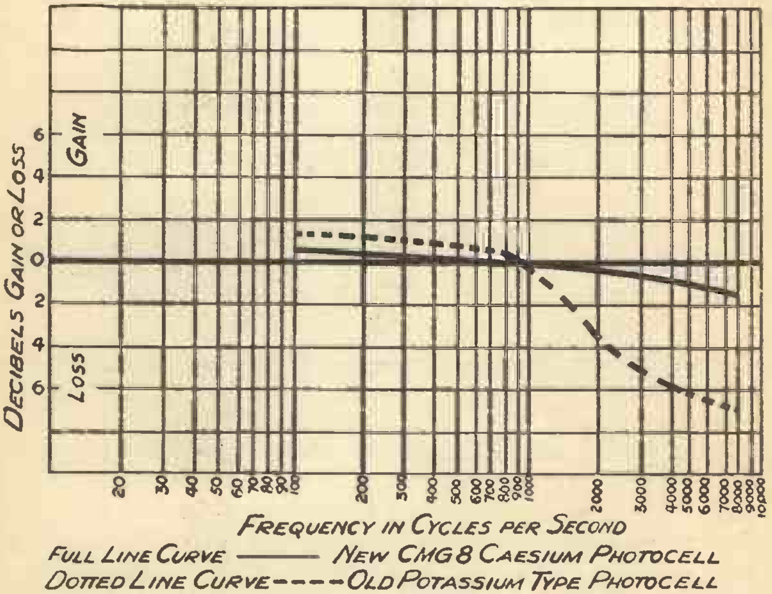

VERY SLIGHT CORRECTION NECESSARY

Fig. 230—A comparison between the characteristics of two types of photo-electric cells. With the new caesium type very slight correction of the higher frequencies is now needed

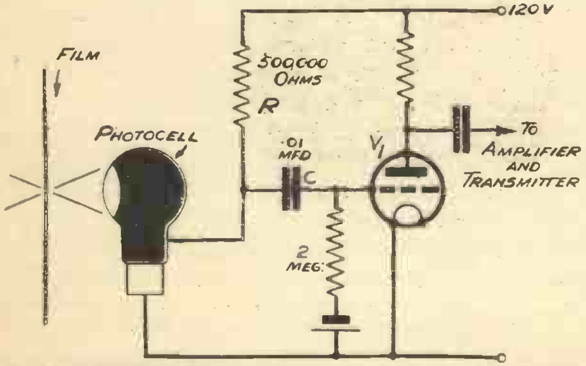

FROM LIGHT TO ELECTRICITY

Fig. 231—The photo-electric cell is connected to the first valve by means of a resistance or capacity coupling

Chapter 26

ULTRA-SHORT WAVE TRANSMITTERS FOR TELEVISION

In which Sir Noel Ashbridge, B.Sc., M.I.E.E., Chief Engineer of the British Broadcasting Corporation, discusses the problem of transmitting high-definition television and compares the apparatus used with that employed for normal sound broadcasting.

Although there are no new fundamental principles involved in television transmitters working on ultra-short wavelengths as compared with those for sound broadcasting on ordinary wavelengths, there are very wide practical differences. The two transmitters may not look very dissimilar at first sight but there are some very interesting problems which have to be solved in order to transmit television, chiefly concerning the actual extent of the performance. In the case of high definition television, a technique is involved which a few years ago would have been looked upon as impracticable and almost fantastic, in fact, it may be said truthfully that recent achievements in this direction are really astounding, particularly to the engineer who is familiar with the design of ordinary broadcast apparatus.

Let us first consider briefly what a transmitter has to do, whether it is intended for vision or sound, confining ourselves to the straightforward methods of modulation. All ordinary transmitters start by generating continuous waves at the required carrier wave frequency, using apparatus which is capable of maintaining an accuracy to the extent of say ten parts in a million. These oscillations are usually produced at a very low level, say a few watts, which are then magnified to the required carrier power of many kilowatts by several stages of amplification, the valves getting bigger with each successive stage.

So far there will be no striking difference whether the transmitter is for ordinary sound or vision, ordinary broadcast waves, or ultra-short waves. It should be mentioned, however, that the design of the ultra-short wave transmitter is much more difficult, mainly owing to capacity effects which cannot be got rid of, such as those between the electrodes of the valves, and the inter-connecting leads, while the latter will give unwanted inductive effects as well.

Having produced a carrier wave the next thing we have to do is to modulate it, either with a band of frequencies corresponding to speech or music, or those corresponding to the scanning of a moving picture or a scene. Some transmitters (such as those used in the B.B.C. Regional Stations) modulate the carrier before it has been magnified to the full rated power of the transmitter, but others modulate during the final stage of amplification. Perhaps it will be easier to follow the problem if we keep in mind particularly the latter type of modulation. If we are going to send out music or speech we must modulate with frequencies all

THE RANGE OF THE LONDON STATION

It has been calculated that the television transmitters at the Alexandra Palace should provide good service up to a distance of 25 miles, and the above map shows the places which will fall within the area covered by that range. Successful reception of television ultra-short wave transmissions has, however, been accomplished at greater distances of which, of course, are audible, and which extend from say 50 cycles per second up to not more than about 10,000 cycles per second, so that if we were working on a wavelength of, for example, 300 metres, i.e., 1,000,000 cycles per second, then the overall band transmitted would be from 1,000,000 – 10,000 to 1,000,000 + 10,000, i.e., 990,000 to 1,010,000 cycles per second. (The figures are given throughout the article in this way for simplicity's sake instead of the more usual kilocycles and megacycles.)

In the case of high definition television we must endeavour to modulate with frequencies extending from almost zero up to somewhere in the neighbourhood of possibly 2,000,000 cycles per second. Obviously, in this case most of the band is above audibility. The upper limit of frequency depends on the degree of definition required, that is, broadly speaking, the number of lines with which each picture is scanned, and the number of complete pictures transmitted each second, the latter determining the steadiness, or absence of flicker, of the picture.

To compare this with the case we took for sound broadcasting, let us assume that we wish to televise on a wavelength of 6 metres, i.e., 50,000,000 cycles per second. In this case our vision transmission would have to cover an overall band of frequencies of 50,000,000 – 2,000,000 to 50,000,000 + 2,000,000 cycles per second, that is to say from 48,000,000 to 52,000,000 cycles per second. If now we work out the overall width of band to be covered in each case as a percentage of the carrier frequency, we find that for vision it is necessary to cover a band equivalent to 8% of the carrier frequency, and in the case of sound only 2% (assuming a wavelength of 300 metres). If we compare the two band width percentages, taking the same carrier wave of 6 metres, then we get 8% as before for vision, and only .04% for sound. This is difficulty number one, but not the only one. Now let us consider what is involved when an attempt is made to produce a band of modulation frequencies say from 0 to 2,000,000 cycles per second. In this case the top *modulation* frequency is higher than the highest *radio* frequency used for ordinary broadcasting, that is to say 1,500,000 cycles per second (200 metres).

Having said this it is hardly necessary to remark that this band of frequencies could not be made to modulate an ordinary broadcast wavelength because one cannot modulate—in the ordinary sense of the word—with a frequency higher than the carrier frequency. Moreover, there are only about 1,000,000 cycles per second between the top and bottom limit of the ordinary medium broadcast band of 545-200 metres. As for the lower limit of modulation frequencies, there are very few sound transmitters working to-day which reach

30 cycles per second with any degree of faithful reproduction, and certainly none which reach anywhere near zero. Thus the modulator system for television must be so designed that it will magnify both radio frequencies and audio frequencies equally at the same time. This is a problem which may not perhaps be very impressive unless one has attempted to build amplifiers which are distortionless to say 15,000 cycles per second, a trifling figure compared with that necessary for television.

These few facts will make it clear that the outstanding difference between the two transmitters which we started out to compare exists in the width of the side band frequencies, that is to say, the modulation frequency band. It is really remarkable to think that satisfactory ultra-short wave transmitters of considerable power, which can handle television, have been evolved after only a very few years of work, particularly when one considers that the present broadcast transmitter has been developed over at least some 12 years of practical working.

Another interesting point arises incidentally from the above, namely that although it is frequently stated that there is room for hundreds of stations between, say, 5 and 10 metres, this is far from true if the stations concerned are transmitting television.

INDEX

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