The Marconi Review

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CONTENTS:

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THE MARCONI REVIEW

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TELEVISION RECORDING

PICTURE quality is the elusive goal in television which so far has defied definition by a single scale of numbers, unless these are allocated on an arbitrary basis against a subjective scale ranging from, say, "excellent" to "completely unacceptable." It is clear that each stage of image transfer from the original scene to the viewers eyes must produce a degradation of picture quality in respect to contrast (or grey scale) reproduction, detail and sharpness and by the introduction of spurious noise, shading, haloes, flare light, ghosts, etc. Some processes can be controlled as to the relative distribution of these three factors; resolution can be improved at the expense of further increase in noise for instance. The introduction of colour television makes it necessary also to consider the effect of these distortions, not only as shown by luminance errors, but also by errors of hue and saturation of the final picture.

Between the original scene and the viewers eyes only a certain total degradation is permissible before he considers the picture quality to be unsatisfactory. How much degradation is allowable depends very much upon the programme interest, hence the engineer's comment that it is a poor programme where the viewers complain of picture quality.

Within the complete television system it would require the wisdom of a Solomon to apportion with complete justice the fraction of the total picture degradation allowable to each of the many processes involved. The vagaries of camera tubes requires a large proportion and poor home receivers with indifferent aerial systems and viewed under poor conditions also claim a relatively large fraction. In between the incredibly complex chain of signal processing, distribution and transmission is surprisingly good but can fall far below its design standard due to inadequate operation and maintenance.

Ideally, all television would be "live" for the immediacy of television exercises a peculiar influence over viewers who quite rightly are prepared to watch a poor programme as it happens rather than a carefully edited film presented later. However, many factors make it essential to be able to record television programmes for subsequent transmission if an economic and balanced service is to be maintained.

The two main reasons for recording, as in sound broadcasting, are to get a time delay or to allow the use of a programme by other stations not connected by links to the originating centre, i.e. to provide a "film network." The time delay may be only a few hours used to bring an event happening early in the day to transmission at a peak viewing hour, or a longer period between a recording made when artistes or studios are available, and a suitable viewing time. Alternatively, recording may be used for repeat performances several weeks after the original performance. In America millions of feet of film a month are recorded merely to offset the time differences across the continent so that top shows can be presented at peak viewing times on both the East and West coasts.

The introduction of a recording/reproducing process brings an inevitable further set of losses. Consider in some detail the complex chain through which the picture has to pass before reaching the viewer. In this case a negative/positive photographic recording process is included:—

(1) Original scene
(2) TV camera lens
(3) TV camera tube
(4) TV camera electronics
(5) Vision Mixer electronics and distribution
(6) Master switching electronics and distribution
(7) Recording monitor electronics
(8) Recording C.R.T.
(9) Recording camera lens
(10) Negative exposure and processing
(11) Printer losses
(12) Positive processing
(13) Film Scanner optical system
(14) Film Scanner Camera Tube or C.R.T.
(15) Film Scanner electronics and distribution
(16) Master Switching electronics and distribution
(17) Link systems (which can be a complex of cable, radio, switching centres, etc., up to several thousand miles long).
(18) Transmitter electronics and aerial system.
(19) Receiver aerial, electronics and C.R.T.
(20) Viewing conditions

Each of these steps is entitled to its share of picture degradation yet the sum total must not lower the initial picture quality below that fully acceptable to viewers. It is thus very true that the higher the initial quality, the more leeway there is as regards the performance of the rest of the system. In fact, bearing in mind the limitations of the rest of the system it will be seen that it is most important that the original scene be composed within these limitations and good recordings start with just this.

If the signal to be recorded is of top quality then the subsequent broadcast signal, whilst inferior to the original, will still be of such quality that the viewer receives a fully acceptable picture. But if the signal to the recorder is of marginal quality then the still further reduction in quality brought about by the losses of the recording/rescanning process may so further lower the picture quality as to make it unacceptable. In such cases the poor recording is too often blamed on the recording system rather than apportioned according to the truth of the matter.

It is clearly important that every effort must be made to reduce the record/reproduce losses to a relatively small proportion of the total and this has been substantially achieved by the last ten years of development in this field. But it is only obtained in well designed equipment, properly maintained and above all operated with care and strict control of each step; particularly those involving the exposure and processing of film.

The story of the development of satisfactory television recording/reproducing systems is a fascinating one which undoubtedly still has much to tell. Not only does it provide a great challenge, but it brings together so many of the " useful arts and sciences," television itself, optics, mechanics, photography in all its aspects, magnetic recording, etc. The problem also has some interesting boundary conditions. If a film process is to be used then there are obvious advantages in retaining the standard 16 or 35 mm. film standards as regards image size, frame rate, etc. Otherwise special projectors will be required, not suitable for scanning normal films. A particular difficulty is that 525 line television has 30 television frames per second, whilst other systems have 25. This works out that on 525 it is fairly easy to record with a film with an intermittent pull-down at the standard rate of 24 film frames per second since an interlaced pair of fields can be recorded, the next field discarded whilst the camera pulls down then the next pair recorded. Scanning the film is correspondingly difficult since 60 television fields have to be obtained from 24 film frames. On the other systems, with 25 television frames per second, scanning is relatively easy since it is satisfactory to run the film at 25 film frames per second equal to television frame rate. But recording is difficult since there is no time, apart from the field blanking period, in which the film can be pulled down.

Consideration of these conditions suggests that there are only two classes of film mechanism suitable for either recording or reproducing on 30 frame or 25 frame televisions systems. The first is that using some form of optical immobiliser with continuous motion film. These virtually lap dissolve successive film frames so that a substantially constant output or input is obtained and synchronism between film and television frames is not required. The second class uses film pulled down in the usual intermittent manner but at such a speed that the pull-down can be phased to occur during the television field blanking period. The so called " fast pull-down."

Many successful solutions have been provided covering part of the problem. Scanning based on storage tubes to allow pull-down time, alternate field recording which is a simple solution for 25 frame systems but discards half the available information (taking an unfair share of the degradation of image detail and signal/noise ratio), double optical flying spot scanning systems for 25 frame systems, and magnetic recording which can only be played back on special equipment and on the original television standards.

Colour television brings many new problems and probably reduces the degradation allowed to the unfortunate recording and reproducing engineer. Whilst his monochrome colleagues now have reason for a certain amount of self congratulation, he is still at the start of a very difficult trail.

It is interesting to note a few dates in this field. In 1927 Baird recorded television on gramophone records; he called it " Phonovision ". In the same year Rtcheouloff took out a patent for the magnetic recording of television. Not until 1934 was recording on film in evidence when Rolf Möller in Germany applied for a patent for recording from a C.R.T. on to film and demonstrated the following year. Also in 1934 Edison Bell England demonstrated their " Visiogram " on film, a waveform recording process.

It took until about 1947 to get workable systems in both Britain and America. The BBC is credited with the first public recorded transmission; of the Cenotaph Ceremony, November 20th 1947, rebroadcast the same evening and later by NBC in America.

G. E. Partington

A 16 mm. TELEVISION RECORDING CHANNEL

PART I

By M. E. Pemberton, A.M.I.E.E.

The importance of television recording is rapidly growing. Apart from the obvious need for a permanent record of historical events there are many other reasons for recording a television programme, perhaps the most important being that these recordings can be exchanged. The cost of putting on a live programme day after day, year after year, is an important factor in delaying the spread of television throughout the world. The television recording, which is easily distributed, is an answer to this problem. To meet this growing demand the Marconi Television Recording Channel BD.679 was developed. The equipment is designed to operate at 625/405 lines 50 fields per second or 525 lines 60 fields per second.

In the following article, which is in two parts, this channel is described and the factors governing its design given. In the first part the overall channel together with the Recording Monitor are described. In the second part the fast pull down camera together with its driving unit, the Flywheel Sync Panel and the power supplies are described.

Introduction

THE aim of the Marconi Recording Channel BD.679 is to produce a 16 mm. film, with the recorded television picture taking the place of the normal photographic image. Many other methods of recording television pictures have been suggested, but on the score of interchangeability, ease of viewing and editing, there is no question that the making of a standard film has great advantages.

Basically this method is quite simple—a cine camera is mounted in front of a television receiver and an image of the television picture is projected on to the film. The speed of the camera has to be synchronized with the television picture repetition rate. Unfortunately, although the method is simple, the production of a good television recording is a most difficult operation. The reason for this lies in the additional stages through which the signal must pass. These are illustrated schematically in Fig. 1. In each stage distortion is introduced, such as loss of resolution, loss of sharpness due to light scatter, loss of contrast, the introduction of random noise, and the mismatch of transfer characteristics. All these distortions tend to turn what was originally a sharp bright picture into an unsharp black and white pattern.

If the aim of any television broadcast organization is to make and use television recordings, not only must the actual recording equipment be as perfect as possible but the rest of the system must also be of the highest quality. It is no longer sufficient to produce a good picture from the original performance either live or from film. It must be possible to record this picture and still produce a good result when transmitted again. In sound broadcasting it is possible to switch from live to record without the listener being aware of the change. The quality of a television recording should not fall very far from this standard.

The Marconi Recording Channel was therefore developed taking into account the television camera and telecine equipment on which the recording is played back.

Of these two equipments the television camera is undoubtedly the most important and one of the reasons why the 4½ inch image orthicon was chosen for the Marconi

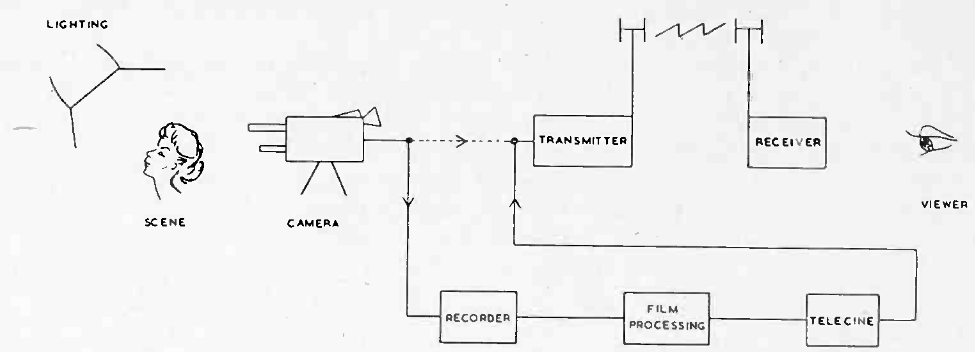


FIG. 1
The Complete Recording Chain.

Mark III Camera BD 687 was because of its better all round performance. The improved signal to noise ratio and resolution, although perhaps not so noticeable on direct transmission, become really of first importance in a recording.

FIELD BLANKING

Standards laid down at the VIth Plenary Assembly of the CCIR International Telecommunication Union, Geneva.

Television System	Field Blanking in Milliseconds		
	Minimum	Maximum	Remarks
405 lines	1·4	—	British
525 lines	0·83	1·33	American
625 lines	1·2	2·0	Recommended CCIR standard
819 lines	2·0	—	French

It is well known that an image orthicon camera tube produces a much better recording than any other camera tube. This is due to a " fault " resulting from a redistribution of electrons on the image orthicon target. This causes white objects to be surrounded by a low level black halo. The opposite tends to happen in the camera lens, on the cathode ray tube screen and in the film, due to light scatter from a white object. These two effects therefore tend to cancel one another and a result unequalled by any other type of camera is obtained.

After the camera, the next important link in the chain is the Telecine equipment on which the recording is played back. Here we have to face the fundamental difficulty, when using film in a television system, of pulling the film through either the camera or the projector.

The interval between television picture or fields for the various systems is given in the table on page 5. The maximum interval given in this table varies between 1·33 and 2 milliseconds. If the film is still being pulled through after this interval, information will be lost on a recording. Time will be lost on telecine.

The shortest pull down time used up to the present day in normal cine equipment is 4 milliseconds in the Bell and Howell 16 mm. projector. In a camera, which has to be made more precisely, it is usually of the order of 10 milliseconds.

Faced with this problem designers have resorted to alternative methods (some of which are most ingenious) which make it unnecessary to use a fast pull down projector or camera.

It is beyond the scope of this article to go into all these methods, but it may be mentioned that the problem of recording in a 525 line 60 field system is easier. It is done by recording only 48 fields and the film is pulled down in the remaining 12 fields. In the 50 field system the two fields that would be saved if the film was run at normal speed is insufficient. A solution of this problem is to run the film slightly faster than normal at 50 fields which is 25 film frames per sec. In the suppressed field system 25 fields are thrown away and the film is pulled through during this time. Alternatively the full information is obtained in some systems by moving the film continuously and immobilizing its movement by an optical compensator.

Recently an alternative method has proved very successful for recording. In this method a long afterglow cathode ray tube is used. The film is pulled through but not exposed during one field. The light during this field is stored in the cathode ray tube phosphor and exposes the film during the next field. The loss of brightness is made up by altering the amplitude of the video signal which is fed to the cathode ray tube grid.

All the above systems have their disadvantages. Perhaps the greatest for the manufacturer is that the same type of camera cannot be used on all television systems. If, on the other hand, it were possible to design a mechanism which would pull the film through in the required time the fundamental problem would be solved. It would be suitable for 50 or 60 field systems, no complicated immobilizers would be required, and the same mechanism could be used in a Flying Spot Telecine as a Projector or in the Recording Channel as a Camera.

Particularly in the post-war period many attempts were made to develop a fast pull down mechanism, perhaps the most successful being that of Isom, working for the R.C.A.[1]. He designed a projector based on a two stage accelerator. Using the principle of acceleration in stages, it was decided to proceed with the development of a fast pull down mechanism suitable for either a 16 mm. projector or camera. The aim was to develop a mechanism which would pull the film through in the minimum blanking period of 1·3 milliseconds. If this was achieved the requirements of all systems would be met. On the other hand even if only a pull down time of between 2 and 3 milliseconds could be obtained, this would be sufficient for the use in a camera, the small loss of information at the top and bottom of the recorded picture only being of the same order as that normally lost in re-scanning.

The fast pull down mechanism finally chosen was one based on an idea[2] suggested by Mr. A. Kingston who personally built the first model for the Marconi Company. The acceleration in this mechanism is done in three stages and no Geneva intermittent accelerator, which was perhaps the weakest link in the Isom mechanism, is used.

The prototype fast pull down mechanism was run at a pull down time as short as 1·3 milliseconds. For a life test it was operated at 2·1 milliseconds pull down for over 3,000 hours without failure or undue wear of the fast pull down elements. This mechanism is fitted in the recording camera which was finally developed by Rank Precision Industries (BAF), Ltd., working in conjunction with the Marconi Company.

A Flying Spot Telecine has much in common with a Recording Channel. In view of this, while the development of the fast pull down mechanism was under way, it was decided to develop a Flying Spot Telecine and a Recording Channel simultaneously, making as many of the units interchangeable as possible. This, of course, simplifies the problems of manufacture and of spare parts.

The Recording Channel will now be described in more detail.

General Description of the Recording Channel

The complete channel consists of the following:—

(1) Recording Channel Stand.
(2) Recording Monitor Type 2660A.
(3) Recording Monitor Head Type 2661A.
(4) 16 mm. Fast Pull Down Camera.
(5) Camera Drive Chassis Type 2662A.
(6) Flywheel Sync Panel Type 2556A an optional unit.
(7) Regulated Power Supply 1·5A Type 2562A.
(8) Auxiliary Power Supply Type 2579A.

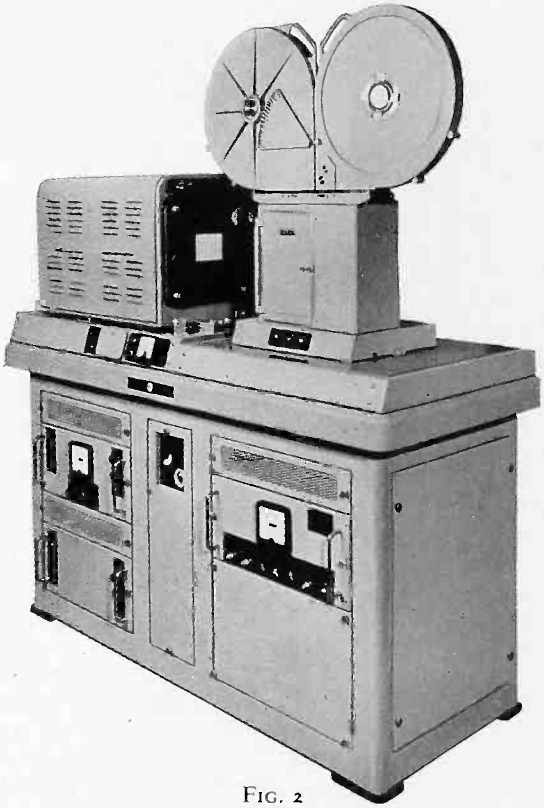


Fig. 2
Recording Channel.

A picture of the Recording Channel is shown in Fig. 2 and a block diagram in Fig. 3.

The Recording Monitor contains all the circuits for forming a high class television picture which is then recorded by the 16 mm. fast pull down camera mounted in the front of the Recording Monitor. The operational controls for the equipment are fitted to the Recording Monitor head. The power supplies for the Channel are obtained from the Regulated Power Supply 1·5A and the Auxiliary Power Supply, while the power for the Camera Motor is obtained from the Camera Drive Chassis. The Camera Drive Chassis synchronizes the speed of the camera with the television picture repetition rate. The standard driving pulses normally available at a television centre can be used for operating the channel. If, however, the video signal is being obtained from a remote source, the Flywheel Sync Panel generates the necessary driving pulses from the incoming signal.

All the above units are complete in themselves and they can be mounted in a variety of ways if so desired.

The channel is designed to include the corrections for the recording process but not for the incoming picture. There is sufficient brightness available from the Cathode Ray Tube to give an adequate exposure on relatively cheap blue sensitive

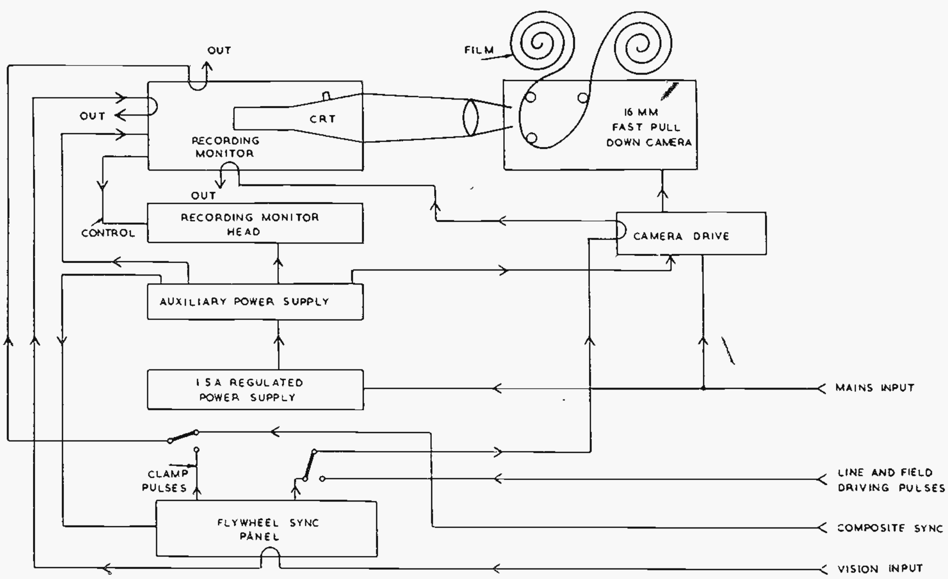


FIG. 3
Block Diagram of Recording Channel.

film. The more expensive high speed panchromatic films need not be used, and if further reductions in film cost are required direct positive recordings can be made. Gamma and aperture correction circuits are included.

No waveform monitor or test signal generators have been fitted to the Channel. The reason for this is that if more than one Recording Channel is being used there is a duplication of equipment. Also, unless the waveform monitors and the test signal generators are carefully calibrated, the Recording Channels may be differently set up. It is recommended that the waveform monitor be either fitted into some central control position or it be placed on a trolley so that it can be wheeled from one equipment to another.

RECORDING CHANNEL STAND

The stand is designed to take all the above units with the exception of the Flywheel Sync Panel which fits into a standard 19-inch cubicle.

In this layout the Recording Monitor, which contains the C.R.T., is mounted via a movable carriage and shock mounts on to the same casting as the camera platform. The C.R.T. and the camera can therefore be aligned without undue difficulty.

The size of the camera platform is such that it can take a 35 mm. camera. The carriage on which the Recording Monitor is mounted enables this unit to be moved backwards away from the camera and rotated. In this position a new cathode ray tube can easily be fitted. When the Recording Monitor is moved back again, locating spigots ensure that it fits accurately to the same position.

The operational controls for the camera are on the camera base while those for the Recording Monitor are mounted on the Recording Monitor Head, which fits round the carriage mount for the Recording Monitor.

The casting to which both the camera and the Recording Monitor are attached is made as heavy as possible to minimize vibration. Anything in excess of 220 lbs. needs special lifting tackle when being handled, so it was decided not to exceed this limit.

The standard height for the centre of the optical path is 4 feet above the floor. This fixed the height of the cathode ray tube in the Recording Monitor leaving plenty of room underneath to mount the Camera Drive, the Auxiliary Power Supply and the 1·5A Regulated Power Supply. To stop the hot air from the unit below from flowing through the chassis above, ventilator panels are fitted above each unit. The hot air from the chassis is deflected out through the grille on the front of the ventilator panel.

In the photograph, Fig. 2, of the Recording Channel the 1·5A Regulated Power Supply is shown bottom left, with its ventilator panel. Over this is the Auxiliary Power Supply. On the top right is the Camera Drive Chassis with its ventilator panel. The space below the Camera Drive is vacant. All the units are the same height and can be drawn out on runners for servicing. In the central space between the units the Input Panel is mounted. All the incoming and outgoing leads are taken to this Panel.

RECORDING MONITOR TYPE 2660A.

A photograph of the Recording Monitor with its side covers off and a chassis folded out for servicing is shown in Fig. 4. A block diagram is shown in Fig. 5.

This unit contains all the circuits for forming the television picture. The quality of recordings made by the Channel are therefore very dependent on its performance.

The Recording Monitor case contains the following assemblies:

(a) The Deflector and Focus Coil Assembly. (Includes Spot Wobble and Focus Modulation coils.)
(b) Field Scan Generator.
(c) Line Scan Generator.
(d) Rectifier Can for EHT Unit (25 kV.).
(e) EHT Unit (25 kV.).
(f) EHT Unit (Focus) only fitted in the electrostatic focus edition.
(g) Blanking Chassis.
(h) Amplifier Chassis.

In order that different types of cathode ray tubes may be used in the Channel, the case has been designed to take from 5 inch to 10½ inch diameter tubes.

Looking at the front of the Recording Monitor the Field Scan generator is fitted into the case at bottom right. To minimize the chance of the line scan being picked up by the Field Scan Generator and thereby spoiling the interlace, the Line Scan Generator is mounted on the other side of the case at the bottom left.

The Blanking Chassis is mounted in the case top right and the Amplifier Chassis top left. All these chassis are of similar design and they can be folded out for servicing.

So that the Channel can be operated with the pulses unlocked to the incoming mains supply, the pick-up from this supply has to be kept to a low level. To help to do this, the heater transformer is placed as far away from the C.R.T. as possible, on the bottom of the case, in the centre, at the back. It is also covered with a mu-metal screen to reduce its stray field. In front of the heater transformer, also down the centre of the case, the Rectifier Can for the EHT Unit is mounted. It is spaced off the bottom of the unit to allow air to enter. In front of this unit is the EHT Unit

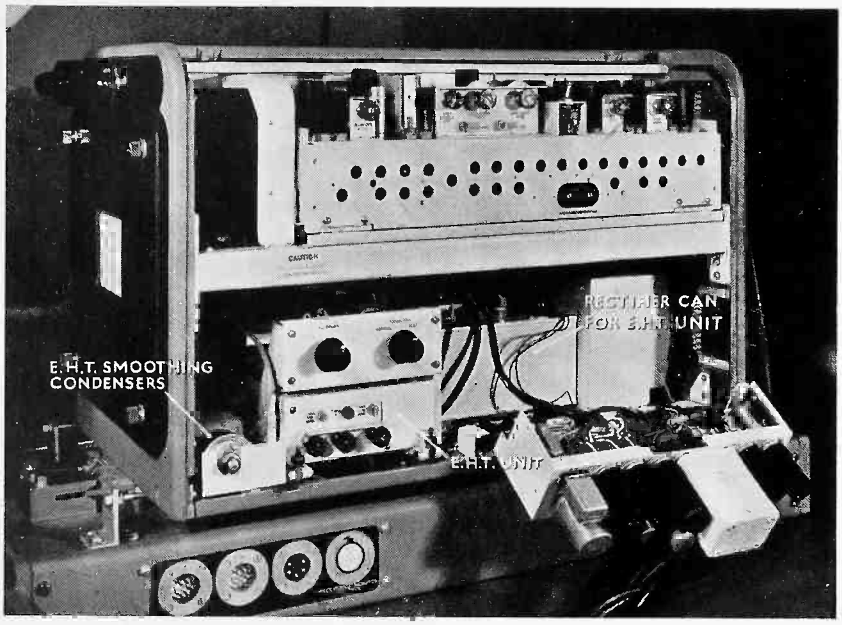


FIG. 4
Recording Monitor.

followed by the two high voltage smoothing condensers inserted into a polythene block.

The EHT Unit comes directly underneath the C.R.T. bulb. Since plenty of space had to be left to take the variously shaped cathode ray tubes the height of this unit is severely limited. To enable it to be serviced it is mounted in a cradle from which it can easily be slid out.

To preserve the focus of the C.R.T. apart from one or two unavoidable items no steel has been used, either in the case or on any of the assemblies. All the fixing screws, etc., are brass.

In some C.R.T.s the final anode connector is brought out very close to its screen. This made it essential to make the front mask of a first class insulation material. Polythene was chosen for this mask. For the same reason the C.R.T. is supported at the front by four insulated arms. These arms are adjustable in length to take the various sizes of cathode ray tubes. To assist in setting these arms to the correct length a calibrated scale is printed on each arm. The neck of the cathode ray tube is supported by a clamp at the rear of the Deflector and Focus Coil assembly.

Fitted to the four front C.R.T. supports are four magnets. The position of these magnets can be adjusted to correct the pin cushion distortion due to the flat screen of the C.R.T.

The Deflector and Focus Coil Assembly

The Deflector Coils and the Focus Coil are mounted on the same assembly. In view of the importance of obtaining the best possible overall focus no expense was spared on this assembly.

To obtain a uniform focus over the whole picture area on the C.R.T. screen both the field and line scanning fields must be uniform. A toroidally wound coil with

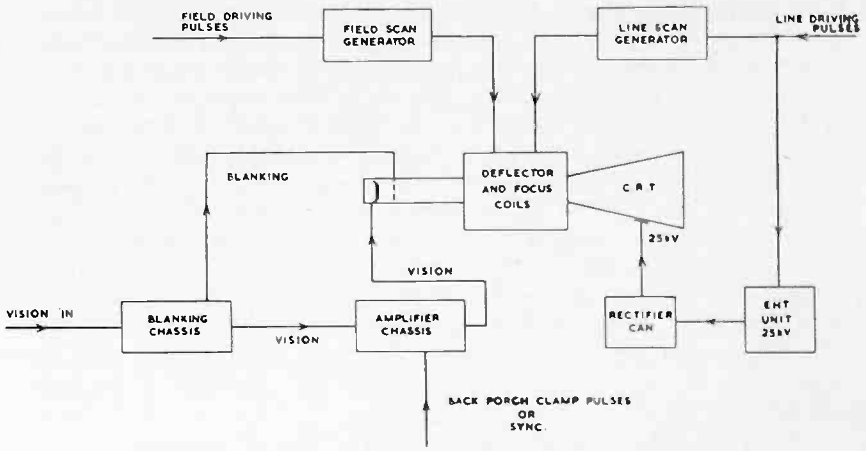


FIG. 5
Block diagram of Recording Monitor.

30 poles was therefore chosen. The field and line deflector coils consist of two toroidally wound coils connected in series opposition. The coils are wound on a $1\frac{3}{4}$ inch long ferrite core. The field coils are on the inside and they are continuously wound in four layers. The cosine distribution is obtained by varying the length of these layers. The 30 pole line coils are wound on top of the field coils in slotted end pieces, which are added after the field coils have been wound. The cosine distribution is obtained by varying the number of turns per slot.

The spot wobble coil is simply a one turn saddle type coil tied to the inside of the above scanning coils. The covering over this wire is made thick to reduce the capacity between the spot wobble coil and the scanning coils.

To reduce the interaction, and hence any S-distortion, between the focus field and the scanning fields, the two coils are kept at least 1 inch apart. Also the Focus Coil is an air wound coil. The choice of an air coil was dictated by the scanning coils, whose efficiency is rapidly reduced by the proximity of any sheet metal. If the focussing field is not uniform an astigmatic spot will result. To avoid this, great care is taken in the winding of the Focus Coil to keep it circular. The individual layers are all interleaved with a single turn of paper. To avoid a bump in the winding the beginning and end of this interleaving is not overlapped. For the same reason these joins are arranged to be displaced circumferentially so that they do not all occur one above the other.

The design of the Focus Coil was a compromise between its size, the voltage drop across it, and the current available. Since the focus supply has to be stabilized the current available is limited by the stabilizing valves. It was thought at first that it would be more economical to use two medium size valves to drive the focus coil.

The focus coil was, therefore, split into two sections of equal resistance, not of equal turns, to reduce the voltage drop and so that each of these sections could be driven by separate valves. It was found better, however, to connect the two sections in parallel and to drive them from one valve. This valve is in the Auxiliary Power Supply.

To avoid distorting the shape of the focussed C.R.T. spot it is essential that the focus coil is placed accurately so that the electron beam of the cathode ray tube goes through the centre and parallel to the focus coil. The focus coil is therefore fitted to an adjustable mounting so that it can be moved or twisted in any direction. To help in this adjustment the normal D.C. focus current can be switched off and an A.C. supply connected in its place. If then both scanning units are stopped a spot will be obtained on the C.R.T. screen. This spot will be unfocussed except for two periods during the A.C. cycle when the current is the correct value for focussing. This will appear on the C.R.T. screen, if the Focus Coil is not correctly aligned on the electron beam, as an unfocussed spot with two separate focussed cores. The spot is deflected as the focus varies. For correct alignment the position of the focus coil is adjusted until the focussed cores coincide and are in the centre of the unfocussed spot.

The focus modulation coil is placed in the centre of the main focus coil. Interaction between the two coils upsets the shape of the line focus modulation field. It is reduced by placing a " shorted turn " in the form of a copper cylinder between the two coils.

Field Scan Generator

The Field Scan Generator is a driven time base of conventional design. It generates the sawtooth current which is fed to the Field Scanning coils to deflect the C.R.T. spot vertically. In spite of the high final anode voltage of 25 kV at the C.R.T., the widest scanning angle likely to be encountered is only 30°. The Field Scan was therefore designed to give an output to cover this deflection angle. The power required is not exceptionally high. It is of the same order as that which is required for an ordinary television receiver with a 90° angle cathode ray tube.

The advantage of using a driven time base is that there is no danger of a loss of synchronism due to drift in the time base circuit or the maladjustment of the lock-in control. The disadvantage is that if the driving pulses should cease, the scanning generator will give no output. Due to the high intensity of the cathode ray tube beam the phosphor will be instantly burnt should this happen. It is therefore essential to have a rapid action C.R.T. protection circuit.

It was found that the usual integrating type of circuit was much too slow in action. Instead a differentiating type of circuit was developed and made to work satisfactorily.

The circuit of the Field Scan Generator is shown in Fig. 6. The sawtooth current is generated by the valves V1-V6 while V7-V9 are the C.R.T. protection valves.

The standard 2 volt or 4 volt negative going field driving pulses are fed to the grid of V_1, which amplifies them and feeds them to the sawtooth voltage generating valve V_2. V_2 discharges the condenser C every time it receives a pulse. Between pulses C charges up linearity through R thus forming the sawtooth waveform. The amplitude of the sawtooth is varied by the " Height " control which alters the charging voltage V. This voltage is made at least ten times the peak value of the sawtooth voltage to obtain good linearity.

This sawtooth waveform is then fed via the two amplifying valves V_3 and V_4 to the output pentode V_5 which feeds a sawtooth current via the transformer T_1 to the Field deflector coils.

To obtain a scanning linearity of 1·5%, feedback is applied by V_6, which samples the current flowing in the scanning coils, to the anode of V_3. The current for centring the C.R.T. beam vertically is applied at the junction of the deflector coils via a constant resistance network.

The parabolic waveform for the field focus modulation is obtained by integrating the anode voltage of the output valve with the $33k$ resistor R_2 and the 1 mf condenser C_2.

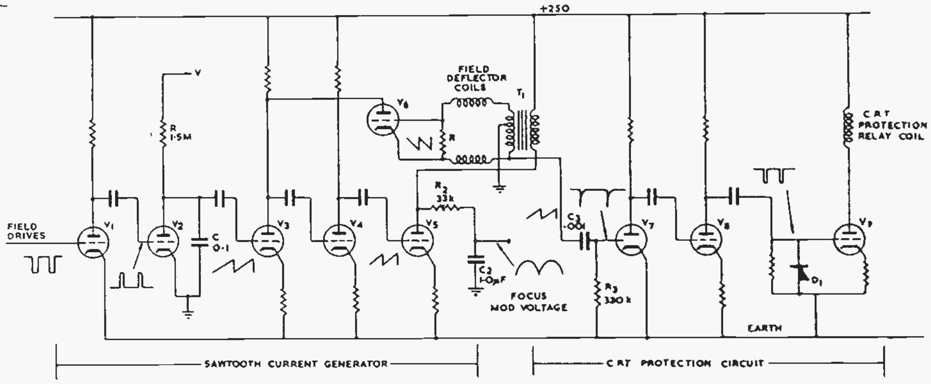


FIG. 6
Field Scan Generator Circuit.

The input to the C.R.T. Protection circuit is obtained from a resistance in series with the Deflector coils. The voltage across this resistance is differentiated by C_3 and R_3 and then amplified and clipped by the valves V_7 and V_8, with the result that narrow negative going pulses appear at the grid of V_9. At the grid of V_9 the germanium crystal diode D_1 establishes the bottoms of these pulses at earth potential. Between pulses therefore the grid of V_9 will be positive by an amount approximately equal to the pulse amplitude. The anode current of V_9 will be high and the C.R.T. Protection relay which is in its anode will be energized. If the sawtooth current in the field coils should cease then the pulses at the grid of V_9 will disappear. The anode current of V_9 will then drop and the relay will become de-energized. The relay has two contacts, one of these switches off the output valve in the 25 kV. EHT Unit and the other increases the bias of the C.R.T. reducing its brightness to zero.

Line Scan Generator

The Line Scan Generator generates the sawtooth current which is fed to the Line Scanning coils to deflect the C.R.T. spot horizontally. Like the Field Scan Generator it is a driven time base and its output power is sufficient to produce a deflection of 40° at 25 kV. This is no more than that required by an ordinary television receiver with a 90° C.R.T. The available regulated HT voltage is 250 volts. This voltage is too low for anything other than a high efficiency line output circuit using a voltage booster diode.

The circuit of the Line Scan Generator is shown in Fig. 7. Like the field scan it can be divided into two parts, the sawtooth current generator V_1-V_6 and the C.R.T. Protection valves V_7 and V_8.

The standard 2 volt or 4 volt negative going line driving pulses are fed to the grid circuit of V_1. To prevent these pulses from increasing the return time of the sawtooth they are differentiated and the positive going pulses resulting from this differentiation are clipped off by the germanium rectifier D_1. The remaining negative going pulses are amplified and fed to the sawtooth voltage generating valve V_2.

To reduce the effect of noise introduced during the discharging time from the input, the sawtooth voltage, which is fed to V_3, is attenuated 10 : 1 by splitting the charging condenser into C_1 and C_2.

The amplitude of the sawtooth, as in the Field Scan Generator, is varied by altering the charging voltage V. The control now becomes the " width " control.

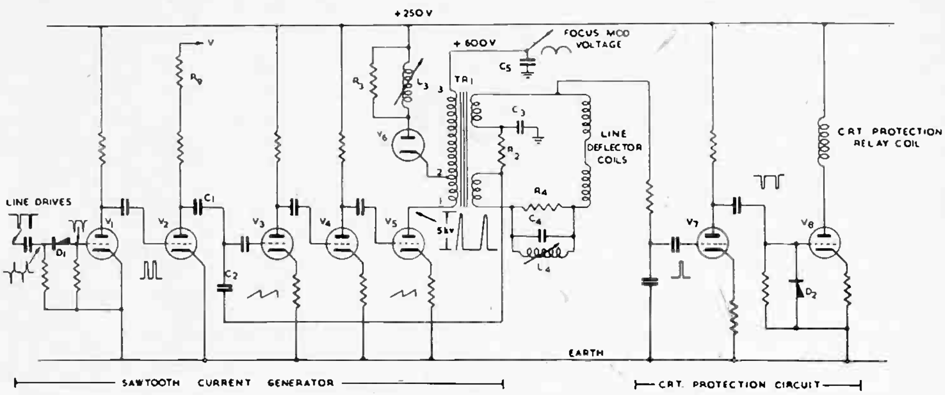


FIG. 7
Line Scan Generator Circuit.

To maintain the same sawtooth amplitude at V_3 when changing the TV system from either 405 to 625 or 525 lines, it is necessary to reduce the charging resistance by shorting out R_9.

The valves V_3 and V_4 amplify the sawtooth waveform and feed it to the grid of the output valve V_5. Although the analysis of the output circuit has been comprehensively dealt with in current literature[3], a simple description of its action will be given. Its action is better understood if the effect of the circuit resistance is at first ignored. In this case the booster diode establishes tap 2 of output transformer TR_1 at the HT voltage of 250 volts. The boost voltage appearing across the boost condenser C_5 at terminal 3 of the transformer is then the sum of this HT and the $n\,L\,\frac{di}{dt}$ voltage across the winding from terminal 2 to 3, where L is the inductance of the scanning coils, n the transformer ratio and $\frac{di}{dt}$ the rate of change of current in the scanning coils. Due to the resistance in the circuit, however, a non-linear output would be obtained if tap 2 remained at a constant voltage. The voltage at tap 2 is therefore modified by the time constant R_3 and L_3. L_3 is made variable to allow for the resistance tolerances in the circuit.

The ratio of the output transformer, which is designed to work at either 625, 525 or 405 lines, is a compromise between two limiting factors; the first is insufficient anode volts on the output valve V_5 due to a high $n\,L\,\frac{di}{dt}$ voltage at large amplitudes on 625 or 525 lines; the second is too large an anode voltage on the output valve V_5, causing excessive anode dissipation, due to a too small $n\,L\,\frac{di}{dt}$ voltage at small amplitudes on 405 lines.

To maintain the required scanning linearity of 1·5% feedback is used. The current in the line coils flows through R_2 and this voltage is fed via C_2 to the grid of V_3.

One of the disadvantages of a high efficiency line output circuit is that to maintain efficiency the Q of the deflector coils must be at least 60. Therefore the damping across these coils must be kept to a minimum. The various leakage inductance circuits are then left undamped and high frequency oscillations, excited by the rapid change in current at the return of the scan, persist into the normal scanning area.

—These oscillations are very difficult to remove without upsetting the efficiency of the output. However, the introduction of a parallel circuit L_4, R_4 and C_4 tuned to the frequency of these oscillations reduces them to a negligible value.

The current for centring the C.R.T. beam horizontally is applied at the junction of the deflector coils and the parabolic waveform appearing across the boost condenser C_5 is used for the line focus modulation.

The C.R.T. Protection circuit works in a similar manner to that of the field scan. The output is sampled at the deflector coils and limited in V_7. The bottoms of the now negative going pulses are established at earth by D_2 in the grid of V_8. The contacts of the C.R.T. protection relay in the anode of V_8 are connected in series with those of the field scan generator.

EHT Unit and Rectifier Can for EHT Unit

Although it is the practice in ordinary TV receivers to obtain the final anode or EHT voltage for the C.R.T. from the line scanning output circuit this is not followed in the Recording Monitor which has a separate EHT Unit. There were three reasons for this decision. Firstly, an exceptionally well stabilized supply is required to prevent the EHT voltage from varying with picture content; secondly, the Recording Monitor was designed to operate over a wide range of line scanning outputs and, thirdly, as high an EHT voltage as possible is required so that the spot size on the C.R.T. is small. An EHT unit was therefore developed which would give the highest voltage and still be of reasonable enough size to fit into the Recording Monitor case. This was done by using a ringing choke type of circuit and immersing the high voltage components in oil. New methods of potting components are rapidly being introduced but there was insufficient evidence of their performance at high voltages to warrant a change away from oil.

A picture of the two parts, the EHT Unit and the Rectifier Can for EHT Unit mounted in the Recording Monitor, is shown in Fig. 4. The size of the Rectifier Can is 8 inches $\times$ 5 inches $\times$ 4 inches and the complete unit gives a stabilized output of 25 kV. $\pm \frac{1}{2}\%$ up to a current of 400 microamps.

The high pulse voltages in the EHT Unit can be picked up by the C.R.T. and appear as a background on the picture. It is difficult to eliminate them completely because the EHT Unit cannot be placed far enough away from the C.R.T. For this reason the EHT Unit is locked to the line scan frequency so that any interference becomes a stationary pattern on the picture.

A ringing choke type of circuit was selected instead of a continuous oscillator, mainly because it can easily be locked to the incoming line pulses and also it is more reliable because of the simple coil arrangement and lack of tuning.

Unfortunately with the standard regulated HT voltage of 250 volts the effective $L\frac{di}{dt}$ drop in the anode of the output valve was too great to allow the circuit to operate at line frequency. Sufficient output was obtained when the $\frac{di}{dt}$ was reduced by using a sub-multiple of the line frequency. To obtain a stationary pattern on the picture for 405 lines this division has to be three and for 625 lines or 525 lines, five.

The voltage pulse obtained from the ringing choke is multiplied by six in a Cockcroft-Walton circuit. The high voltage metal rectifiers, together with the choke and condensers, are immersed in oil in the Rectifier Can. High voltage terminals, which at 25 kV. would be almost as big as the box itself, are avoided by feeding the leads straight into the can through oil-tight glands. On the end of each lead is a small plug no bigger than the diameter of the lead itself. This enables the leads to be changed.

The circuit of the EHT Unit is shown in Fig. 8. Standard line driving pulses are fed to the grid of V_1, which amplifies and passes them to the blocking oscillator V_2. Depending upon the system, the time constant CR is set so that V_2 only fires once for either three or five input pulses.

The sawtooth across C is fed to the grid of the output valve V_3 and its shape is adjusted so that the voltage drop in the anode of the output valve is a minimum during the valve conduction.

The output 25 kV. is stabilized by V_4 and V_5 using both current and voltage feedback. Voltage feedback is introduced from R_2 which is connected across the first multiplier section of the Cockcroft-Walton circuit. The voltage feedback, ideally, should have been taken right from the output, but R_2 would then be very large indeed. Current feedback is obtained from R_3.

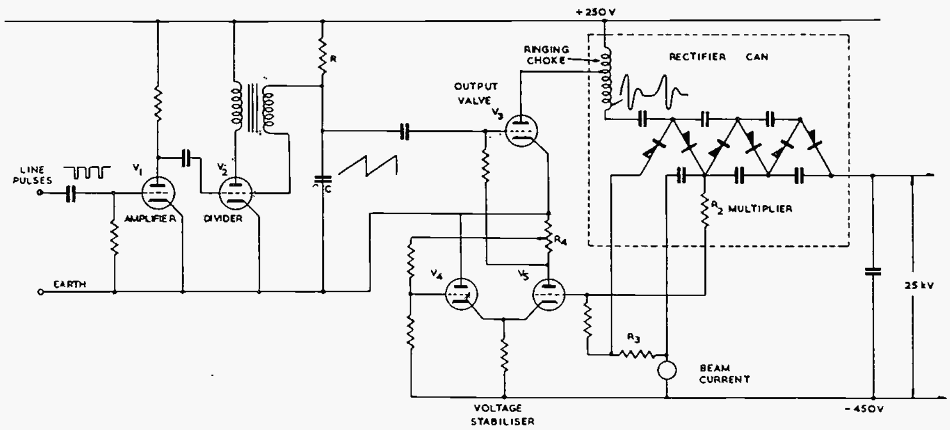


FIG. 8

EHT Unit (25 kV.) Circuit.

V_4 and V_5 are cathode coupled and the EHT voltage is set by adjusting the grid voltage of V_4. Any change in the output voltage will alter the grid voltage of V_5 with reference to the grid of V_4. The anode current of V_5 will change, alter the grid voltage of V_3 and hence cancel the change in output volts.

The effectiveness of this correction depends on the gain of V_4 and V_5. Their gain is increased by introducing a small amount of positive feedback, insufficient to cause instability, by taking the grid circuit of V_4 to a tap on R_4 in the anode of V_5.

EHT Unit (Focus)

This unit has to be fitted if an electrostatic focus type of tube is used. At first sight it would appear that a simple tap across the 25 kV. EHT Unit would serve. Unfortunately cathode ray tubes, such as type 5ZP16 or 5WP15, take two to three times more current from their focus supply of 7 kV. than their final anode current.

There was no alternative but to add this additional unit. It is 7 inches long by 4 inches wide by 4 inches high and it fits into the top of the Recording Monitor case.

The circuit is a copy of the 25 kV. unit but only two metal rectifiers are needed instead of the six. These rectifiers are fitted with the valves in the same chassis. Also due to the lower voltage no division is necessary and the circuit can operate at line frequency.

The same focus modulation voltages as are used in the magnetic edition can be fed into this unit to obtain focus modulation. A single output pentode valve type 5763 is used to modulate the focus electrode.

Blanking and Amplifier Chassis

The Recording Monitor was designed to accept a standard composite video signal of 1 volt $\pm$ 6 dB. Since the video part of this composite signal is only 0·7 volts the minimum video signal amplitude will be 0·35 volts. To cater for different cathode ray tubes the output must be at least 100 volts, so the gain of the video chain must be at least + 49 dB.

Because there was plenty of room in the Recording Monitor for this amplifier together with the other auxiliary circuits described later, it was decided to fit, into the video chain, transfer characteristics and aperture correction circuits normally built as separate units. This results in quite an appreciable reduction in the number of valves when compared to the number of valves required, if these corrections are done in separate units. For example, it was estimated that, in addition to the correction circuit, at least three valves would be required in each unit to amplify the video input up to the required level, at least three more valves for feeding the signal out at standard level into 75Ω and three valves for clamp pulse generation; making a total of eighteen additional valves, if the corrections are made in two separate units.

A circuit of the video chain is shown in Fig. 9. Valves V_1 to V_{10} are in the Blanking Chassis and valves V_{11}-V_{24} in the Amplifier Chassis. The circuit can be divided up into the following sections; V_1-V_5 the sync stripper; V_6 the first gain control; V_7-V_{10} the high frequency correctors and pre-amplifier; V_{11}-V_{17} the transfer characteristic correctors consisting of the black stretch circuit V_{11}-V_{15} and the white stretch circuit V_{16}-V_{17}; the second gain control and signal reverser V_{18}-V_{19}; the output stages V_{20}-V_{22}; and the back porch clamp pulse generator V_{23} to V_{24}, for driving the D.C. reinsertion double diodes V_2, V_{11}, V_{14} and V_{21}. These sections will now be described in more detail.

Sync Stripper

This circuit is necessary because the black stretch, when used, increases the amplitude of the synchronizing pulses to such a value that they would overload all following stages.

The incoming video signal is fed to the grid of V_1 and after amplification is fed to the grid of V_3, where its D.C. is re-established by the double diode V_2. The synchronizing pulses are removed when the germanium diode D_1 ceases to conduct. The level at which this takes place depends on the relative grid volts of V_3 and V_4, which can be altered by adjusting the voltage V_a on the grid of V_4. The output of the sync stripper is taken from the cathode of V_5. To make the action of D_1 more precise, feedback is applied from the anode of V_5 to the cathode of the first valve V_1.

First Gain Control

The black and white stretch circuits require a fixed input for correct operation. Therefore to allow for the $\pm$ 6 dB change in the input level a gain control is necessary. The obvious place for a gain control is in the cathode of V_5, but unfortunately the change in capacity as the slider of the gain control was altered, upset the frequency

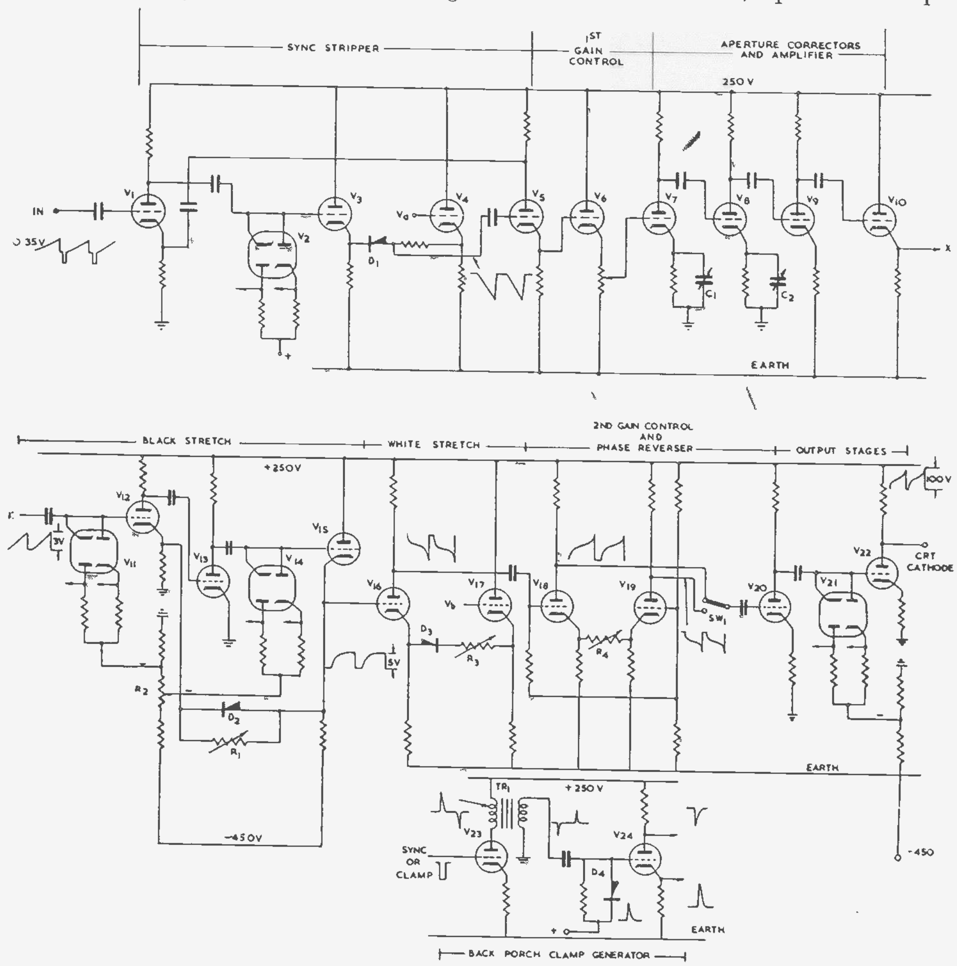


FIG. 9

Circuit of Video Chain.

response of the sync stripper. Therefore V_6 had to be added and the gain control was fitted into its cathode.

Aperture Corrector

To correct for the losses in C.R.T. aperture and the film, the signal is fed from the gain control to the two high frequency corrector valves V_7 and V_8. V_7 and V_8 are identical stages and the high frequency boost is obtained by an adjustment of the variable condensers C_1 and C_2, which are across the relatively high cathode resistors.

The maximum amount of correction obtainable is as follows:—

+ 6 dB at 3 Mc/s.
+ 10 dB at 5 Mc/s.
+ 12 dB at 7 Mc/s.

The signal from the high frequency correctors is amplified by V_9 and fed out of the Blanking Chassis into the Amplifier Chassis by the cathode follower V_{10}.

The overall flat response up to this point in the circuit is $\pm$ 0·2 dB at 8 Mc/s. The output level is 3 volts.

Black Stretch

The first circuit on the Amplifier Chassis is the black stretch. This circuit together with the white stretch circuit enable the " toe " and " knee " of the photographic positive and negative to be compensated. Also this circuit enables the overall transfer characteristic of the recording process to be matched to a particular telecine, or recording C.R.T. The signal is fed to the grid of V_{12} where its D.C. is re-established by the double diode clamping valve V_{11}. The signal is then amplified by V_{12} and V_{13} and fed to the grid of the output valve V_{15} where its D.C. is again re-established by V_{14}. The relative value between the cathode voltages of V_{12} and V_{15} determines whether the germanium diode D_2 will conduct or not. When D_2 is conducting feed-back is applied between the cathode of V_{15} and V_{12} reducing the gain. The D.C. level of the signal at the grid of V_{15} is so arranged that during the black parts of the signal D_2 is not conducting and during the white parts it is conducting. The gain in the blacks is controlled by the variable resistance R_1 which is connected across the diode D_1. The range over which the black stretch becomes effective is controlled by R_2 which alters the bias of V_{15}.

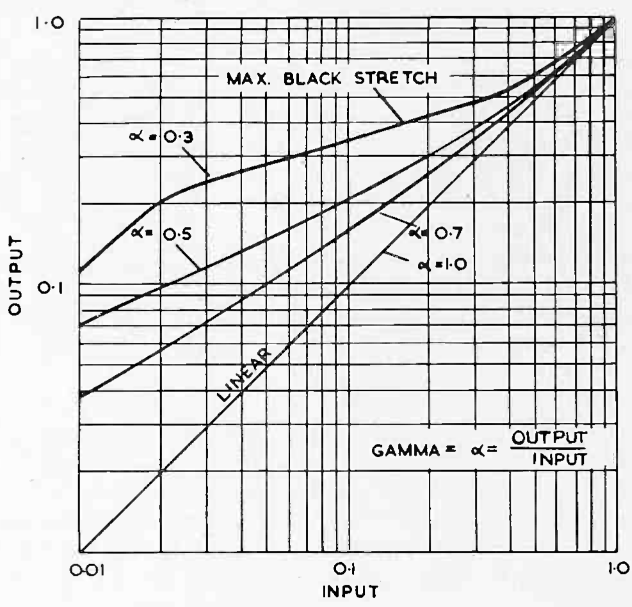


FIG. 10
Black Stretch Curves.

A series of typical curves are shown in Fig. 10. In practice if a single germanium diode is used the curve produced has too sharp a " knee " at the point the diode starts to conduct. This can be smoothed out by introducing other diodes which are arranged to conduct at slightly different levels. It should be noted that the curve is a power law when the diodes are conducting.

White Stretch

The signal is fed from the output of the black stretch circuit at the cathode of V_{15} to the grid of V_{16} which is the first valve of the white stretch circuit. This saves the introduction of another clamping double diode valve. White stretch is obtained when the germanium diode D_3 conducts and increases the gain up to a maximum of four times by reducing the cathode resistance of V_{16}. The value of this increase in gain can be adjusted by altering R_3. The range over which the white stretch is operative is adjusted by altering the grid voltage V_b of V_{17}. Like the black stretch, to get a smooth transition, it is necessary to employ several germanium diodes. Typical curves are shown in Fig. 11.

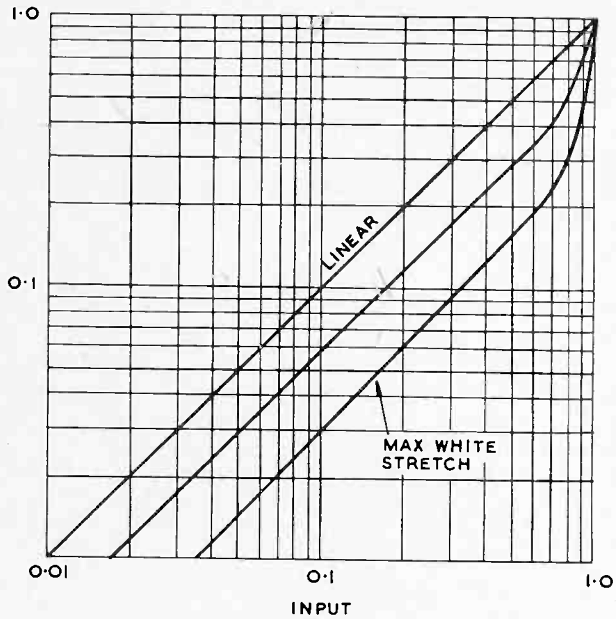


FIG. 11
White Stretch Curves.

Phase Reverser.

The normal photographic process is to make a negative first and then from this print a positive. However a positive film can be made straight away by displaying on the cathode ray tube a negative picture. To do this the signal is fed out from the white stretch circuit to a phase reversing stage consisting of the cathode coupled valves V_{18} and V_{19}. Either a positive or a negative going signal can be obtained, depending which anode is selected by the switch SW1.

Another gain control is required so that output voltage of the amplifier can be adjusted to suit different C.R.T.s. This can be done quite simply by varying the cathode coupling between V_{18} and V_{19} with R_4.

Output Stages

After the reversing stage the signal is amplified by V_{20} and V_{22} and taken to modulate the cathode of the C.R.T. The D.C. is re-established by V_{21} in the grid of V_{22}.

The circuit was designed to give an output of 100 volts and the overall linear frequency response of the video chain is as follows:—

Flat $\pm$ 0·2 dB to 7 Mc/s.
— 1 dB at 8 Mc/s.
— 4 dB at 9 Mc/s.
— 10 dB at 10 Mc/s.

Back Porch Clamp Generator

After the synchronizing pulses, in a standard composite signal, the level is at black for 4-5 microseconds. This part of the video signal is commonly known as the " back porch ". The circuit, consisting of V_{23} and V_{24}, generates positive and negative going pulses known as " back porch " clamping pulses coinciding with this period. These clamping pulses are fed to the D.C. re-establishing double diodes which conduct for the duration of these pulses, charging their respective grid coupling condensers to the voltage at the junction of the two diodes. If the grid condensers remain charged then all subsequent voltage changes will be with reference to this level, i.e., the D.C. has been re-established.

The Back Porch Clamp generator circuit is designed to work off either composite synchronizing pulses or an already properly made back porch clamp pulse.

The synchronizing or clamp pulses are fed to the grid of V_{23}. The primary inductance of the transformer T_1 is made low so that the synchronizing pulses are differentiated. The negative going part of this waveform whose start coincides with the leading edge of the synchronizing pulse is removed by V_{24}. The positive going part whose start coincides with the end of the synchronizing pulse remains and appears at the anode and cathode of V_{24}.

The pulses from the anode and cathode of this valve are fed to the D.C. re-establishing double diodes. The differentiation has in effect produced a phase reversal, therefore when a clamp pulse which is only partially differentiated by T_1 is used instead of synchronizing pulses, the output to V_{24} has to be reversed. This is easily done by reversing the connections from the secondary of TR_1 with a switch.

Blanking Generator

It is necessary to use separate blanking on the cathode ray tube for two reasons; firstly the cathode ray tube may have to be operated with its black level set up—in which case the return lines will just be visible; secondly, when making direct positive films there will be a negative picture on the cathode ray tube in which case the return lines will be at peak white.

When a remote signal is used it is necessary to generate from this signal the driving pulses, normally supplied from the station waveform generators, in the Flywheel Sync. Panel. To avoid generating mixed blanking in this unit, the blanking for the C.R.T. is generated from the line and field driving pulses.

The circuit of the Blanking Generator, which is on the Blanking chassis, is shown in Fig. 12. Standard line pulses are fed to the grid of V_1, where they are widened by the action of germanium diode D_1. When the line pulses go negative, the germanium diode D_1 conducts and shorts out R_1; when the line pulses go positive D_1 cannot conduct and their time of rise is slowed up by the time constant R_1C_1. Similarly, the rise time of the field pulses which are fed to the grid of V_2 are slowed up by the time constant C_2R_2. The resultant field and line pulses are mixed together in the anodes of V_1 and V_2 and fed to valves V_3 and V_4. V_3 and V_4 are so connected that as soon as the current in one valve is reduced the other valve starts to conduct and rapidly cuts it off. The circuit behaves like a switch and the change over from one valve conducting to the other depends on their relative grid voltage which can be adjusted with R_1. Now the input signal whose D.C. voltage is established by D_3 is much larger than the voltage required for the change over. If, therefore, R_1 is adjusted so that the change over takes place over a slowed up section of the pulse, a widened pulse will be obtained in the anode of V_4. Due to the switching action of V_3 and V_4 the time of rise and fall of this widened pulse will be small.

The signal from the anode of V_4 is fed to the output valve V_5. The grid of the cathode ray tube is coupled directly to the anode of V_5 and the blanking voltage output is at least 100 volts.

Spot Wobble Oscillator

The action of the Spot Wobble is to deflect the C.R.T. spot vertically to fill in the spaces between the scanning lines. It is essential that this should be done on a recording, otherwise interference patterns will be obtained on replay due to beats between the two sets of scanning lines, one on the recording and the other from the telecine.

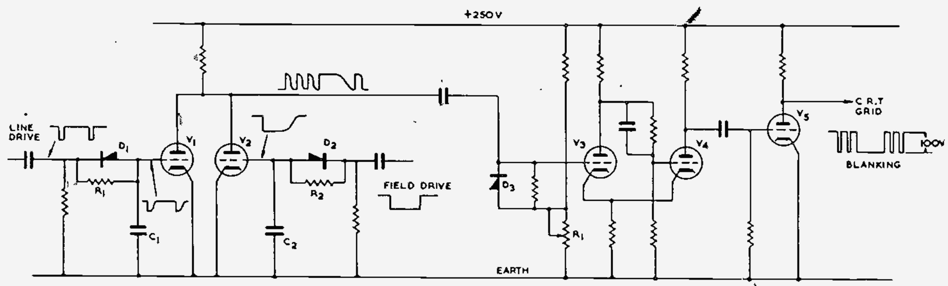


FIG. 12
Circuit of Blanking Generator.

The Spot Wobble oscillator is fitted on the Blanking chassis, and is a conventional cathode coupled oscillator operating at 25 Mc/s. The output is taken from a tap on the oscillator coil and is sufficient to remove a line structure of 200 lines.

Focus Modulation

Due to the flat surface of the C.R.T. screen the focus current required for the edges of the raster is slightly different from that required in the centre. To correct this, the focus current is arranged to alter in sympathy with both the scans by feeding out from both the line and field scanning generators parabolic waveforms to a valve fitted on the Blanking chassis. This valve feeds the correction focus current through the separate focus modulation coil fitted inside the main focus coil on the Deflector and Focus Coil Assembly.

RECORDING MONITOR HEAD

This unit fits round the Recording Monitor mounting assembly and contains the following controls:

Vertical Centring Control.
EHT on and off.
Beam Focus Control.
Beam Current Control.
Beam Current Meter.
A neon to indicate the Line Scan is operating.
A neon to indicate the Field Scan is operating.

References

(1) Fast-Cycling Intermittent for 16 mm. Film by Warren R. Isom, Journal of the SMPTE, Vol. 62, Jan. 1954.

(2) British Patent Application No. 30543/54.

(3) Reactive Time Bases by A. B. Starks-Field, B.Sc., Journal of the British Institute of Radio Engineers. Vol. 12, No. 10, October, 1952.

THE EVALUATION OF PICTURE QUALITY IN TELEVISION

By N. R. Phelp

In an article which appeared in the Marconi Review, *Nos.* 102 *and* 103, *a method was described for evaluating the performance of picture reproducing systems in terms of the picture quality parameters, brightness, contrast, resolution and viewing distance. The present article describes the application of this technique to a television recording channel using a 4½-inch Image Orthicon television pick-up tube. The television channel and the complete recording system are compared with conventional motion pictures.*

Introduction

THE evaluation of picture quality in television systems by the method previously used and described in the *Marconi Review** has been extended to cover a 4½-inch Image Orthicon film recording chain.

The equipment consisted of a 4½-inch Image Orthicon camera working on closed-circuit at 625 lines, sequential, 50 pictures per second. The bandwidth of the video circuit was 12 Mc/s (flat) with a sharp cut off to about -40 dB at 16 Mc/s. At the time of the test the phase distortion brought about by the sharp cut was only partially corrected, resulting in an overshoot after transitions; whilst aperture loss in the camera pick-up tube and the cathode ray tubes was approximately corrected. The image orthicon was operated with highlights just above the knee of the characteristic; no precise correction was included for the high overall gamma (about 2) of the display and recording C.R.T.s, although some measure of compensation was available in their adjustable " background brightness " settings.

Apart from the visual display on a 15-inch monitor, the picture was presented on a 6-inch blue-screen recording C.R.T. working at 25 kV., to a standard 35 mm. motion picture camera. Alternate fields of the picture were electronically blanked out, the film being pulled down during these blank periods, so that the pictures were recorded on the film at 25 per second.

An essential feature of this type of test is that the apparatus shall be adjusted to give good reproduction on a normal scene before the tests commence. Such a scene is provided by an illuminated transparency, which is then replaced by a series of test patterns without any alteration being made to the controls. To enable this to be done without driving any part of the chain on to an unsuitable part of its brightness characteristic, the test objects (having similar brightness values to the scene) are presented in an illuminated surround whose average brightness is similar to the scene's.

This arrangement permits some of the test patterns to be presented at a higher brightness than the normal highlight in the scene and allows the effects of this slight overloading to be observed without completely upsetting the operation of the camera.

An essential feature of the operation of the chain tested or, indeed, any television

*" The Evaluation of Picture Quality with special reference to Television Systems," L. C. Jesty and N. R. Phelp, *Marconi Review*, No. 102, pp. 113-135, and No. 103, pp. 156-186.

equipment is the accurate maintenance of pedestal at a suitable level in order to preserve the shape of the transfer characteristic.

This pedestal is introduced into the video signal immediately after it leaves the camera head amplifier, its primary purpose being to provide a clean (noise-free) reference level in the signal. At the time of these tests, in the absence of more sophisticated circuitry, it was also used to reduce the slope of the overall transfer characteristic (camera to recording cathode ray tube). It was therefore considered not only permissible, but imperative to allow this one control to be operated during the sequence of the tests in order to maintain the pedestal at constant amplitude independent of slow drifts which were a source of worry at that time.

Test Procedure

In accordance with established routine, the television monitor was viewed by one observer stationed close up to it, the condition referred to as $0 \times H$. This observer was supposed to determine the capability of the system independently of the effects of the visibility of the human eye at a distance. Six observers viewed from a distance equal to four times the picture height ($4 \times H$) and six from eight times the picture height ($8 \times H$). These were actually the same six observers who took turn and turn about. Observers were asked as usual to note the criterion of judgement used such as not visible (N), just visible (J), visible (V), clearly visible (C), as the case might be. The observer at $0 \times H$ of course used only the criteria N or J.

To minimize the labour involved, observations were made at the centre of the field only.

In addition to these monitor observations the test patterns were " telerecorded " on to Kodak 35 mm. Negative film type 5398. This blue-sensitive stock is usually used for variable-area sound recording but when developed to a low gamma has a characteristic curve similar to the usual panchromatic negative picture stock—Plus X. The use of a non-panchromatic film stock offered attractive advantages. It is cheaper than Plus X, it is reputed to have a higher resolving power and it can be handled in a standard red safelight.

Its drawback is that it is coated on a clear base which makes halation troublesome by reducing the photographed contrast, and hence the resolution, of fine detail. It is not known what gain may be expected on balance, but since these tests were made a new stock has become available, type 4398, which has the same emulsion as 5398 but is coated on a grey base. This film is issued specifically for telerecording. Another drawback to both these stocks which has become apparent is the difficulty of maintaining consistent processing at the low gamma required to give normal positive prints. This might be overcome by using a cathode ray tube display with a reduced contrast range, thus enabling the film to be processed at a higher gamma (1·5 instead of 0·75) which would give more consistent results. It was considered advisable, however, to record on negative material which could be processed to gammas which are normal (or near normal) in the motion picture industry. Prints made at various printer lights from a telerecorded negative of the setting-up scene were carefully examined to determine the light most suitable and this grading was used for printing the positive from the test patterns.

The brightness transfer characteristics were obtained, as previously described (loc. cit.), using a set of calibrated neutral filters in place of the resolution patterns and measuring the reproduced brightness on the cathode ray tube, or the density on the recording film.

Test Results

The negative of the resolution test patterns was examined at low magnification and the shots in which patterns were not resolved were removed before printing. The print was examined in the same way but so far has not been observed by a team under projection conditions. The results of the visibility tests so far carried out are shown in Figs. 1 and 2. The results are plotted for three contrasts of test object 0·97, 0·44 and 0·21 in the vertical columns from left to right. The horizontal rows refer to the three viewing distances, $0 \times H$, $4 \times H$ and $8 \times H$ from top to bottom.

Fig. 1 refers to Vertical Test Lines and Fig. 2 shows the results for Horizontal Test Lines, for observers at $0 \times H$, $4 \times H$ and $8 \times H$ from the television monitor.

For comparison some information obtained from projected 35 mm. motion picture film in 1949 has been extracted from Fig. 13, *Marconi Review* No. 102, page 126, and is shown in Fig. 3. The results obtained from examination of the film used for those tests are shown in row (*a*) of Fig. 4 (also extracted from Fig. 13, *Marconi Review* No. 102). Row (*b*) and (*c*) are for low magnification of the telerecorded negative and positive, for vertical and horizontal test lines respectively.

Transfer characteristics are shown in Figs. 5 and 6 for the recording chain up to the positive film stage together with a typical characteristic as used for motion picture work in cinemas. It should be noted that these curves refer to the film density and not to projected brightness. Further distortion of the curves in Fig. 6 may occur on projection due to veiling glare in the projection lens or due to light scattering from one screen element to another. These effects are usually small as will be seen from curve (d) Fig. 21, *Marconi Review* No. 102, page 132.

Figs. 7 and 8 show the monitor curve and a "Jones" diagram* showing the effect of the high gamma positive process on the low gamma negative. The negative was exposed at a reduction of about 5·5 : 1 in a specially designed camera incorporating a Vinten Everest motion. The f/2 lens used on this camera was computed by Taylor, Taylor & Hobson, Ltd., for use with blue light and its resolving power is well maintained at the rather short conjugates associated with a 5·5 : 1 reduction. Its focal length is 2 inches and it was worked at full aperture. The G.E.C. 6-inch recording cathode ray tube with zinc sulphide phosphor was operated at 25 kV. and run at 100 μA peak. The negative was processed to a IIb control gamma of 0·75, but the actual gamma to the C.R.T. exposure differs from the IIb gamma owing to reciprocity law failure. This arises because the IIb sensitometer gives a series of exposures of constant intensity and varying time, while the C.R.T. exposure is of constant time and varying intensity. In addition the intensity/time relationships are very different in the two cases, the IIb time varying between 1/500 and one second whereas the C.R.T. exposure is in the order of microseconds.

To determine the relationship between IIb gamma and the actual C.R.T. gamma a neutral density wedge placed over the face of the tube and illuminated by the raster was photographed and put through the standard processing. Measurement of the resulting densities showed that the actual gamma was 0·72. It is important to know this relationship in order to be able to quote to the film laboratories the processing conditions to produce a required negative characteristic. The overall gamma from scene to negative varies between 0·10 and 0·78 over the range of input brightness $B/16$ to B and there is little effective gamma below $B/64$. The negative was printed on to Kodak 7302 Release Positive at Cinex printer light 5. The overall gamma of the positive varies between 0·40 and 1·83 over the same 64 : 1 brightness range.

*The evaluation of Negative Film Speeds in terms of Print Quality. Lloyd A. Jones. Journ. Franklin Inst. 227.3 and 4 1939.

In order to compare the camera/display noise-limited sensitivity with other systems, the curve corresponding to $0 \times H$ observations (N/J) for low contrast test objects ($C = 0{\cdot}21$) has been added in its appropriate place to Fig. 25 (loc. cit.) and the whole diagram is reproduced here as Fig. 9. Basic information relating to the system performance is given for comparison with Table 1 (loc. cit.) below.

Pick-up Device	T_{max}	B	A	N	ø	t_b	Q_b	Q_e
(f) Image Orthicon (Type P811)	385	35	$\frac{8{\cdot}0}{10^3}$	8	$\frac{8{\cdot}2}{10^4}$	$\frac{1}{25}$	$\frac{4{\cdot}25}{10^{-11}}$	$\frac{5}{10^{-3}}$

Examination of Results

Examination of Figs. 1 and 2 shows that vertical test lines are generally slightly better resolved than horizontal lines. A horizontal preference is shown in some instances at $8 \times H$, high contrast high brightness, and in various low brightness cases. This is probably a spurious effect due to moire patterns which occur both at higher and lower values than the true resolution. The observer at $0 \times H$ who was certainly not skilled at differentiating real from spurious resolution also showed this preference.

Ignoring these few ambiguous results it will be seen that the circuit constants chosen have resulted in very nearly equal resolution in the two conventional directions but the sharpness has since been improved by the introduction of differential equalization.

Comparison of these monitor results with the curves for projected 35 mm. motion picture film (Fig. 3) shows that at other than $0 \times H$ the television system shows superior results both in resolution and in the brightness range of patterns which are reproduced. Although the $0 \times H$ results for film show better resolution at high brightness values the brightness range is still limited but it must be pointed out that the motion picture results were obtained as the result of work which took place in 1948 and there are indications that they do not represent the best modern motion picture practice. In comparing film and television, account must be taken of their totally different resolving-power v. reproduced-contrast characteristics as discussed elsewhere.*

To make the recorded film evaluation fully significant, tests should be conducted either by projection in a cinema or by scanning in a television system according to the ultimate requirement. In this instance the objective was to make a film by television means which was indistinguishable on projection in a cinema from a film shot in a conventional film camera. In view of improvements which were about to be made in the apparatus at the time of these tests it was not considered necessary to embark on cinema projection evaluation but rather to make interim assessments from a low magnification examination of the film.

The results plotted in Fig. 4 rows (b) and (c) show once more the equality of horizontal and vertical resolution. By comparison with Figs. 1 and 2 the degradation due to the recording process is apparent. Although the film is capable of recording practically the full brightness range as shown on the television monitor (for vertical test lines) losses occur both at high and low brightness. Losses due to light scattering in the film camera optics and in the film will inevitably reduce the resolution, particularly at low contrast, and measurement of the spot size on the recording cathode ray tube for various beam currents indicate that an increase in

* The Quality of Television and Kinematograph Pictures. L. C. Jesty and N. R. Phelp, British Kinematography, 22, No. 4.

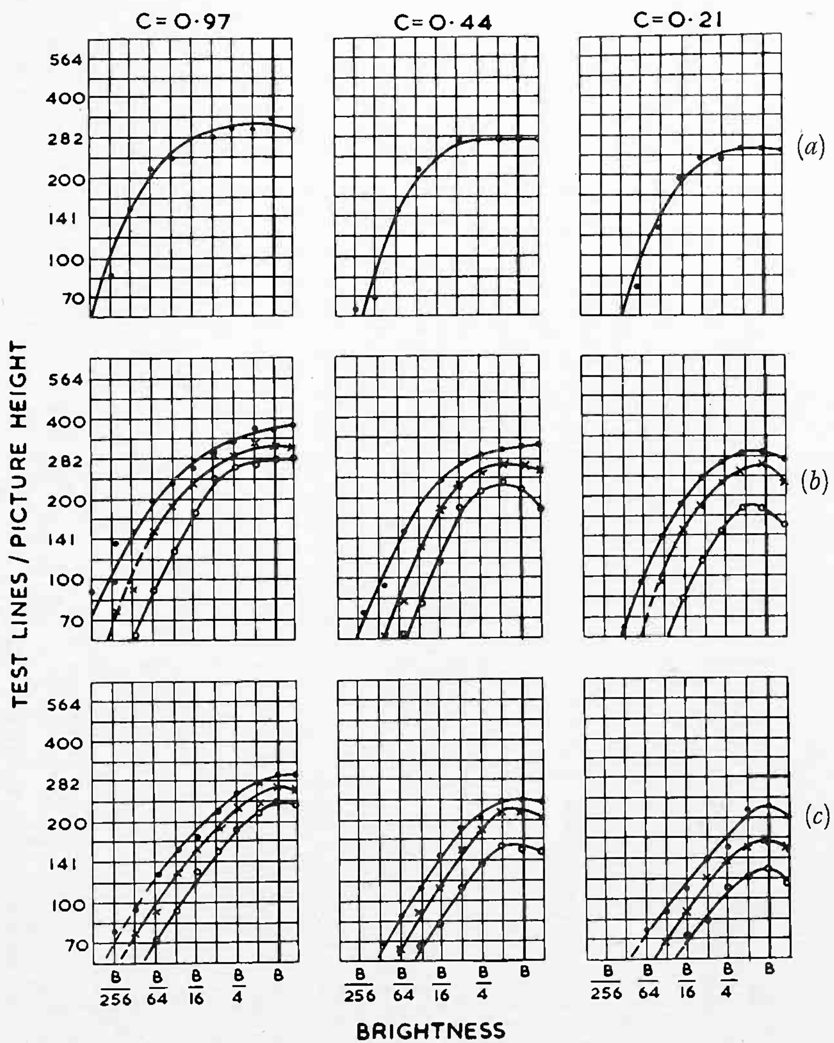


Fig. 1. VERTICAL TEST LINES

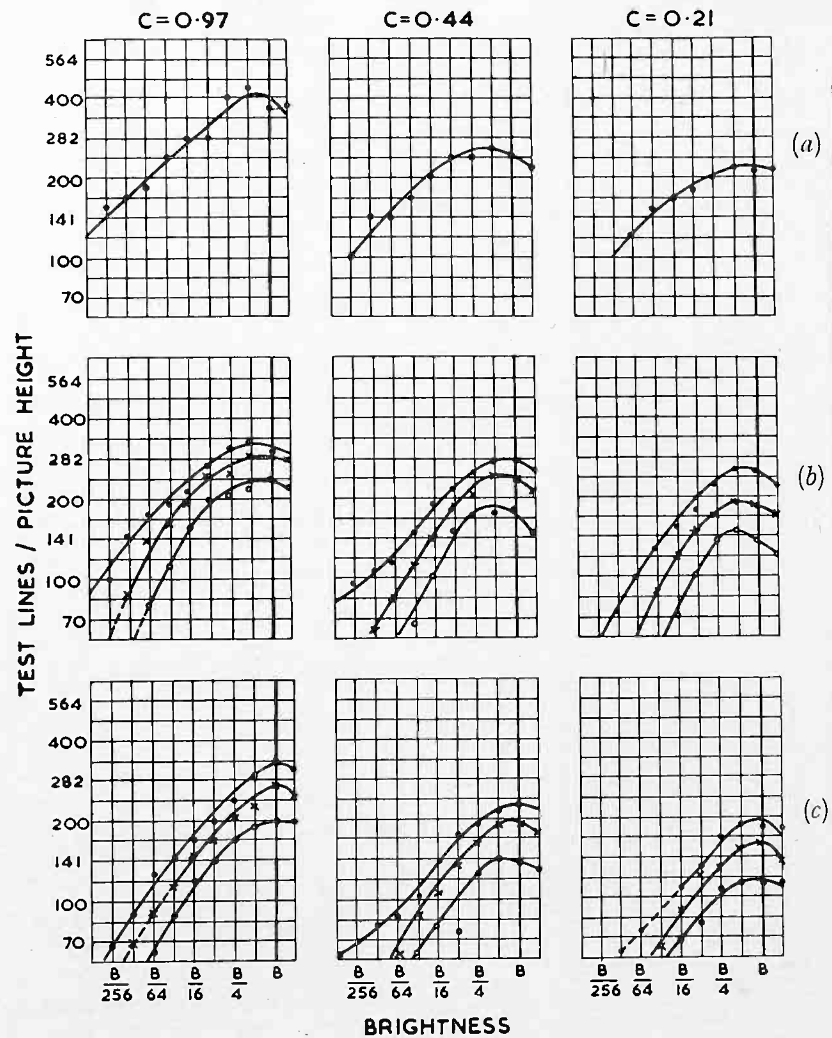


Fig. 2. HORIZONTAL TEST LINES

625-LINE, 50 FIELDS/SECOND, SEQUENTIAL, 4½″ IMAGE ORTHICON CAMERA. TRANSMITTED BY LINE TO 15″ MONITOR C.R.T.

English Electric Image Orthicon Camera Type P811; photocathode size 1·2″ × 0·96″. 3″ T.T. and H series O lens, bloomed, $f/2$ working at $f/8$. Highlight Brightness B at camera = 35 ft. lamberts. Receiver Highlight Brightness = 12·3 ft. lamberts. Picture size = 12″ × 9″.

(a) 0 × H, 1 Observer. N ● J. (b) 4 × H, 6 Observers. N ● J ✕ V ○ C. (c) 8 × H, 6 Observers. N ● J ✕ V ○ C.

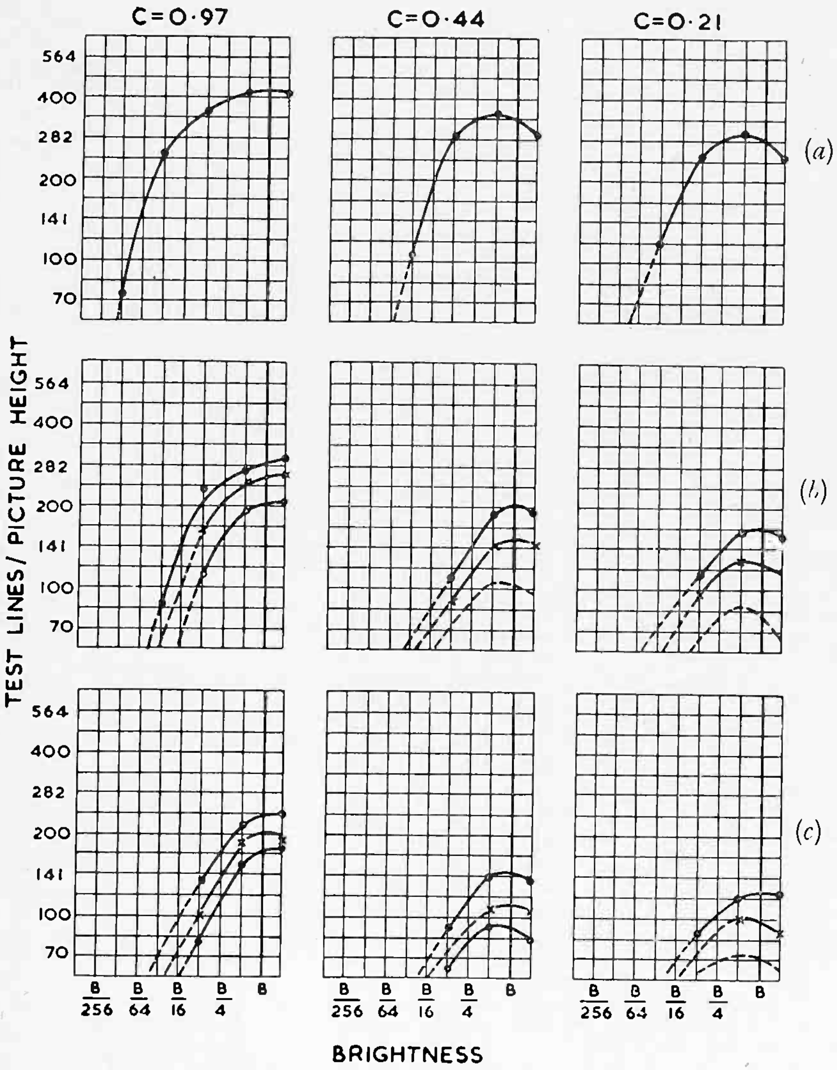


Fig. 3. 35 mm. MOTION PICTURE FILM

Extracted from Fig. 13 *Marconi Review*, No. 102, p. 126

(a) 0 × H, 1 Observer. N ● J
(b) 4 × H, 12 Observers. N ● J ✱ V Ø C } 1948/49
(c) 8 × H, 12 Observers. N ● J ✱ V Ø C

AVERAGE HORIZONTAL/VERTICAL TEST LINES.

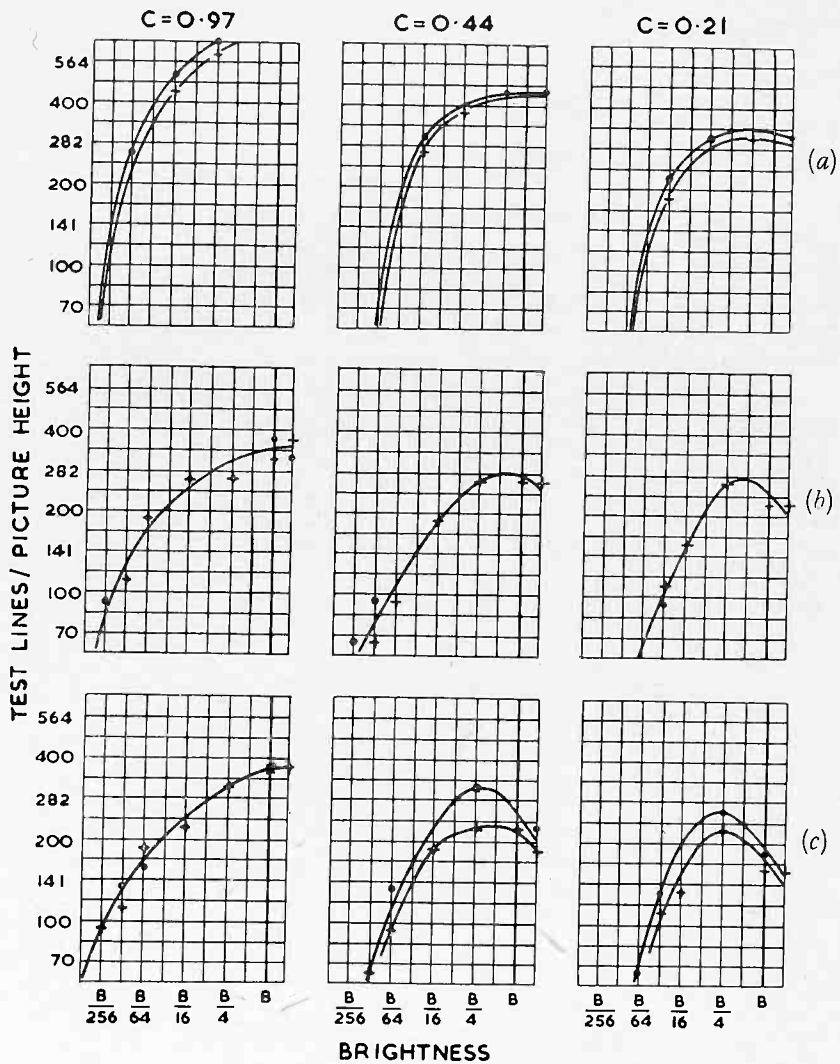


Fig. 4.

625-line 50 fields/second, sequential, $4\frac{1}{2}''$ Image Orthicon Camera. Alternate fields recorded on 35 mm. film.

English Electric Image Orthicon Camera Type P811; photocathode size $1{\cdot}2'' \times 0{\cdot}96''$. 3″ T.T. and H Series O lens, bloomed, $f/2$ working at $f/8$. Highlight Brightness B at camera = 35 ft. lamberts. Recording receiver picture size $4\frac{1}{4}'' \times 3\frac{3}{16}''$. Highlight brightness of the recording tube screen about 150 ft. lamberts.

(a) AVERAGE H/V TEST LINES.

(b) VERTICAL TEST LINES.

(c) HORIZONTAL TEST LINES.

35 mm. Motion Picture negative and positive examined at low magnification, extracted from Fig. 13(a) *Marconi Review*, No. 102.

Negative Recorded on Kodak 5398. —●—
Printed on 5302 positive stock. —+—
Examined at low magnification.

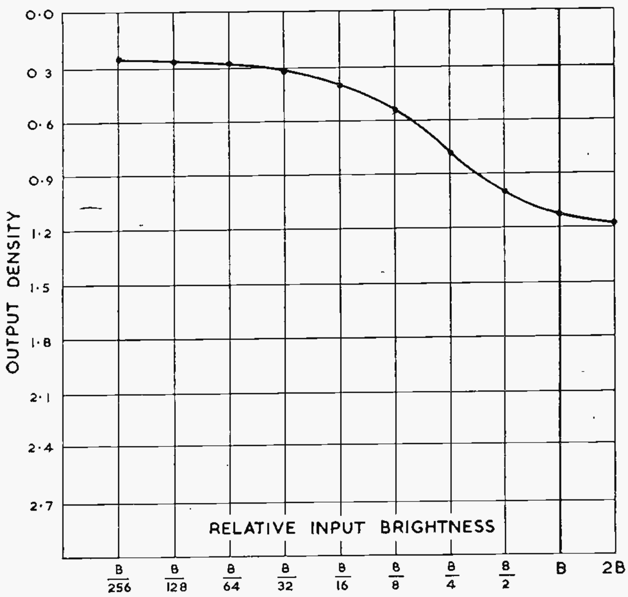


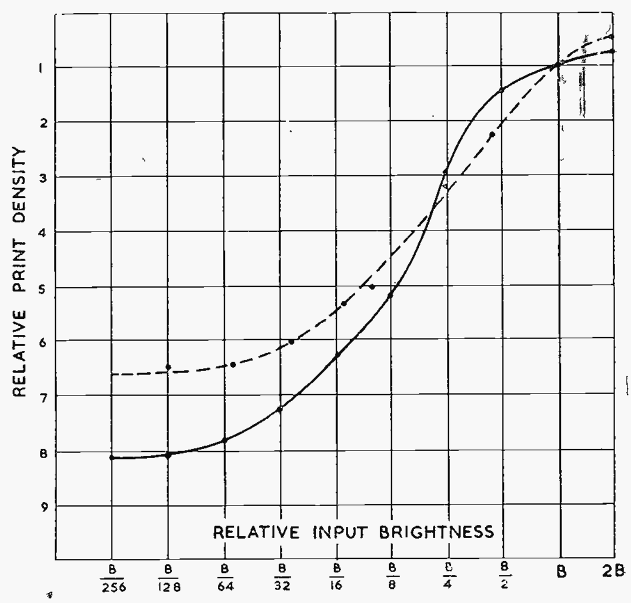
Fig. 5 (*left*)

Density/Brightness Characteristic of Recorded Negative Film. B is the highlight brightness of the original scene, 35 ft. lamberts (*Figs.* 1 *and* 2).

Fig. 6 (*right*)

Density/Brightness Characteristic of Recorded Positive Film. Printed from the negative of Fig. 5.

Recorded Positive ——— *Motion Picture Pos.* - - - - -



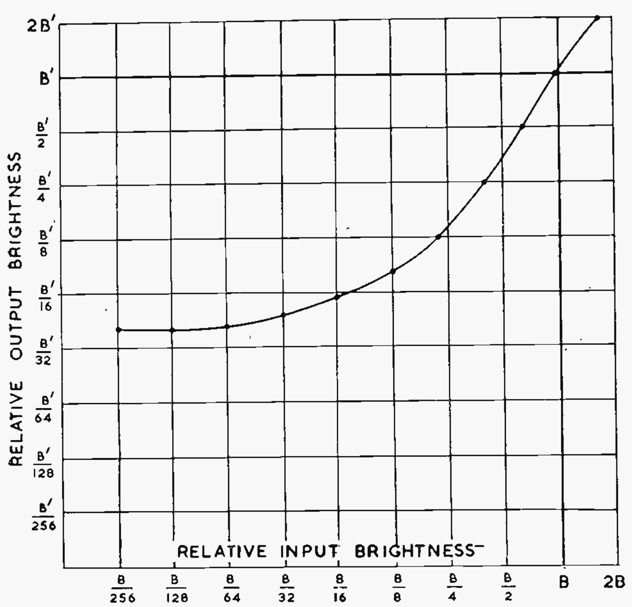


Fig. 7 (*left*)

Brightness Characteristic of Recording Channel Monitor. B is the highlight brightness of the original scene, 35 ft. lamberts, B′ is the monitor highlight brightness, 12·3 ft. lamberts (*Figs.* 1 *and* 2).

this size may well be responsible for the reduction in resolution at high brightness. The loss due to printing as shown in row (c) needs some explanation and it is thought that this is probably due to some slipping or unsteadiness in the particular printer mechanism used which although insufficient to produce a noticeable degradation at high contrast reduces the limiting resolution at the lower contrasts.

In row (a) the appropriate curves for normal 35 mm. film have been plotted and almost everywhere show such film to be capable of adequately recording the television image.

The negative film density/brightness characteristic (Fig. 5) shows rather less density for the highlight brightness B than is normal due to flattening of the curve in this region. This is a combination of highlight "crushing" in the television camera and slight saturation of the recording C.R.T. screen. The overall characteristic up to the print stage (Fig. 6) shows that at least as many tones are reproduced as in conventional filming with the addition that a larger tone range is present on recorded film. Here again it must be emphasised that the normal film characteristic was taken in 1948 and could no doubt be extended using modern equipment and techniques.* Kodak, Ltd., in a booklet "*The Use of Motion Picture Films in Television*" suggest that print densities of ordinary films may attain 2·4; equivalent to step 8 on the relative print density scale of Fig. 6 which means a very similar range to the recorded film. The difference between the two curves would then lie in their shape, notably in the high slope of the recording in the brightness region around $B/4 - B/8$, and the reduced slope above, say, $B/3$, resulting in facial tones, for example, being reproduced with false values.

The transfer characteristic to the recording channel monitor (Fig. 7) also shows a restricted reproduced brightness range although the picture quality in other respects is shown to be good (Figs. 1 and 2). Reconciliation of these facts has been made in *Marconi Review*, No. 103 in connection with quarter-plate photographs, the argument briefly being that the eye is capable of exchanging a reduction in contrast for an increase in brightness.

Fig. 8 illustrates the way in which the original scene brightness values are transferred to the negative film (low gamma), thence by the unity gamma printing process to the positive (high gamma). The slight curvature at the end of the positive film curve, corresponding to the original scene highlight region, adds of course to the other effects already mentioned in referring to the negative (Fig. 5) in flattening the overall characteristic (Fig. 6).

One important factor determining the usefulness of a picture reproducing system is its sensitivity, and the relationship between this recording camera chain and other systems is shown by the group of curves in Fig. 9. It might be as well here to dwell on the meaning of these curves. They represent sections of constant visibility surfaces, the position at which the sections are taken being determined by the contrast of the test patterns to which the curves apply (in this case $C = 0{\cdot}21$). All points on all the curves shown in this figure then refer to detail of equal visibility, the abscissa giving the number of quanta per picture required to reproduce the appropriate number of test lines per picture height using the N/J criterion.

Reference to the article in the *Marconi Review*, No. 103 reveals that these constant visibility curves are limited in a number of ways. The resolving power is limited by lens aberrations, scanning spot sizes, video bandwidth, etc.; the brightness limits are determined mainly by the flattening of the transfer characteristic; and at low

* A new transfer characteristic for Motion Picture film, Plus X negative: 5302 positive, has been established quite recently which is much straighter and has a much greater density range than the curve shown in Fig. 6. It has in fact about the same overall contrast as the recorded film but with a reasonably straight part extending from $B/128$ to $B/3$.

contrast noise also has a limiting effect. It is shown in the previous paper that this noise limit may be represented by a diagonal line whose slope is given by

$$\frac{\log (T_1 - T_2)}{\log (Q_{p1} - Q_{p2})} = 0{\cdot}5$$

tangential to the visibility curve; such tangents have been drawn for various systems and the intersections of these with the base line indicate their noise limited sensitivities.

It is then immediately obvious that by this criterion the $4\frac{1}{2}$-inch Image Orthicon camera chain (f) is about ten times as sensitive as the 3-inch chain (d) tested in 1949.

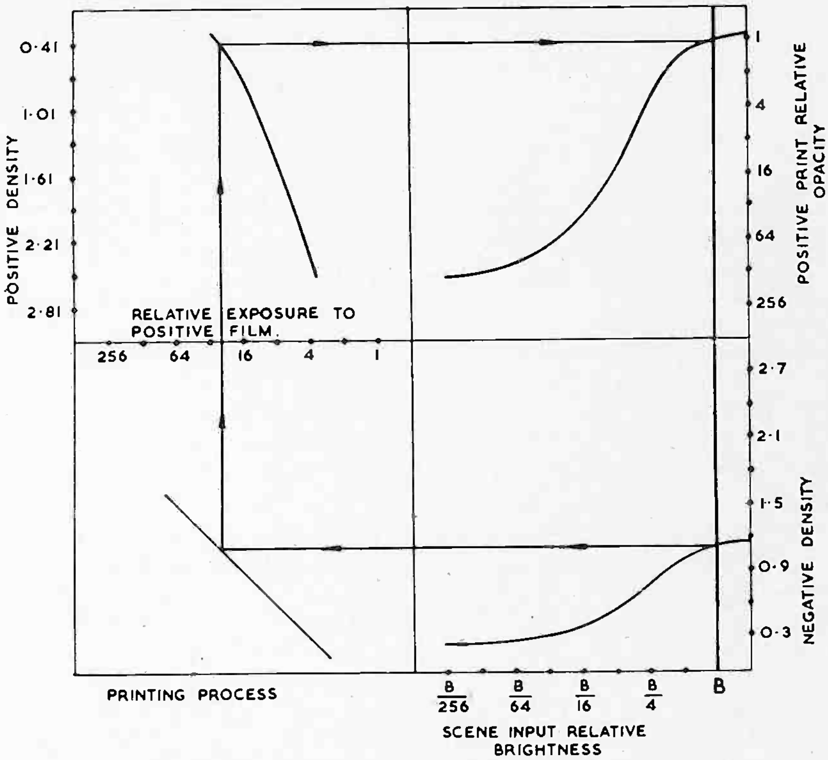


FIG. 8

Tone Reproduction Diagram. B is the highlight brightness of the original scene.

It is also capable of reproducing a greater range of test lines/picture height over a greater range of brightness.

Similarly, comparison with motion picture film (c) shows the $4\frac{1}{2}$-inch Image Orthicon to be some four times more sensitive than Plus X film, to be capable of reproducing over a slightly larger range of brightness but to have a limiting resolution in this particular application of 260 test lines/picture height as against 290 for the film. This all refers of course to close inspection, i.e., $0 \times H$.

It is now generally accepted that limiting resolution should not be used as a basis for picture quality appraisal, and if the more realistic viewing distance of $4 \times H$ is taken as well, then the television system shows everywhere a margin of goodness over motion picture film.

A proviso must here be made again on behalf of the film as there is a strong probability that better figures would be obtained if the film tests were repeated at the present time. Even allowing for some improvement it is doubtful if the curves would show the film to be capable of reproducing patterns at such low brightness values as the television camera. The image orthicon is in this respect rather

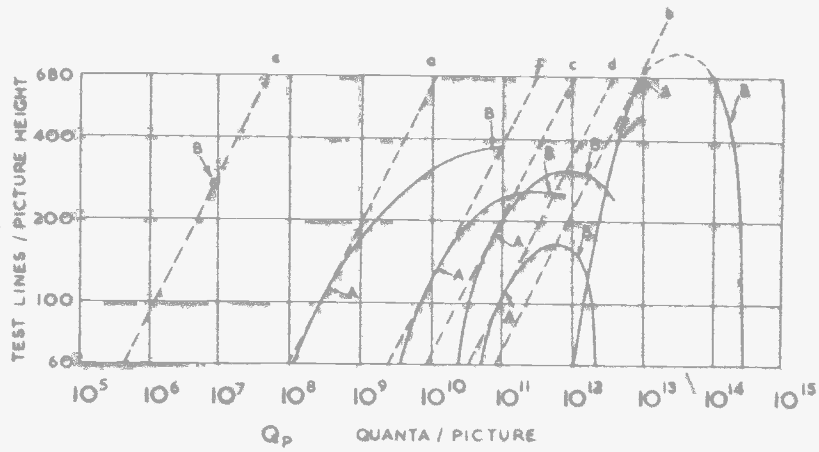


FIG. 9

Relative performance of different picture reproducing systems in terms of resolution and incident radiation on camera target for low contrast test objects, C = 0·21, at N/J criterion.

(*a*) *The Eye.* (*d*) *Image Orthicon.* 5655.
(*b*) *Quarter-Plate photographs.* (*e*) *Quanticon.*
(*c*) 35 *mm. Motion Pictures.* (*f*) *Image Orthicon,* P811.

surprising, and although it may be partially explained by a brightness-contrast exchange as mentioned in referring to Fig. 7 it is doubtful if this is a complete explanation.

Conclusion

It was suggested in 5.2. of the article in *Marconi Review* No. 102 that a 600 line interlaced television system with spot wobbling and a bandwidth of 5 Mc/s would be capable of resolving at $4 \times H$ all the low contrast detail at that time resolvable with 35 mm. film projection. Making the necessary changes for the present sequential scanning system which does not require spot wobbling but requires additional bandwidth because of the higher picture repetition rate it will be seen that this forecast has been confirmed not only at low contrast but at high contrast as well. This is borne out by the good quality of the recorded pictures which are distinguishable from direct film mainly by subtleties of tone rendering and some effects typical of the image orthicon camera tube.

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