ENGINEERING TRAINING SUPPLEMENT

No. 7

BASIC PRINCIPLES OF TELEVISION LIGHTING

by

H. O. Sampson and R. de B. McCullough

BRITISH BROADCASTING CORPORATION

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The authors wish to record their indebtedness to Miss Mary Malcolm for so patiently acting as model for the photographs in Fig. 1. In deference to Miss Malcolm it should be stated that these photographs are not intended to be ideal portraits, or standards to be copied except for experimental purposes.

Acknowledgment is made to the Institution of Electrical Engineers for permission to quote certain material contained in the Paper *Television Lighting Technique* by H. O. Sampson presented to the I.E.E. Television Convention 29 April 1952. The material concerned is:

'Soft' and 'hard' light, pages 3 and 4
Lighting and make-up, pages 8 and 9
Multi-camera technique, including Figs. 2 and 6, pages 9 to 14
Aspects of lighting of full-scale production, pages 15 and 16
Table of operational lighting values, page 22

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PREFACE

This BBC Engineering Training Supplement has been written as an introductory handbook for those interested in Television lighting technique. A general knowledge of Television production methods is assumed.

A number of books are available on lighting for still photography but there has been no way for the beginner other than by trial and error to relate this information to the complicated task of lighting Television performances, in which both actors and cameras are in continuous motion. The present volume is designed to fill this gap. It contains the substance of verbal instruction given by senior members of the lighting staff to trainees, concurrently with practical work in the television studios. To make the book self-explanatory for the general reader, photographs of typical studio demonstrations have been inserted. Nevertheless, it must be emphasised that lighting, like playing the piano, is essentially a practical subject, and cannot be learned merely by reading a textbook.

The writers think it important to stress that this manual does not describe nor recommend any standardised code of procedure. The effective application of lighting to entertainment demands a high degree of imagination coupled with great flexibility of technique in face of the ever-changing problems of studio presentation. Any attempt to impose a systematised routine, or to save imaginative effort by listing a series of foolproof lighting recipes as is done in some photographic books, will, in the writers' opinion, ultimately reduce the visual effectiveness of the programmes. Accordingly, the rules and procedures discussed in this book must be considered solely as exercises for the beginner; he will not become an expert until he knows when to forget them. For this reason, the material presented here is unsuitable for use in examinations.

This manual contains information collected from a large number of sources and it is therefore impossible to acknowledge them individually. Many of the basic ideas mentioned will be found treated in greater detail by the authorities quoted in the bibliography.

BASIC PRINCIPLES OF TELEVISION LIGHTING

1. INTRODUCTION

1.1 Light

Light as a subject is divided into a number of different branches. The student will need to know something about each of them, so the type of information included in each branch is analysed briefly below:

Physical Optics

This subject includes the basic laws of light propagation, formation of shadows, reflection, refraction, colour, lenses and optical instruments. A text book of School Certificate Physics is a good source of basic information. More specialised works on photography or lighting often give a compressed version which is either too complicated or too 'popular'.

Illuminating Engineering

This subject comprises the design of light sources and lighting equipment for all purposes, e.g. illumination of roads and public buildings. A specially important branch of the subject is Photometry, which deals with the measurement of light and colour.

Lighting for Theatre Stage

Although not directly suitable for Television, a great deal of special machinery has been developed for the theatre, such as the cyclorama, effects like clouds and fire, and very elaborate dimmer switchboards and control devices for colour mixing. Television workers often meet producers who can only explain what they want in terms of the theatre. It is well to remember that every Television performance is at heart a theatrical performance, and every branch of theatre-craft is therefore worthy of attention.

Lighting for Photography

In lighting a theatre stage we are dealing directly with the human eye. In photography, the lighting is basically required to operate a camera: the audience never sees the original scene or lighting, but only a photographic image of it. Accordingly, a knowledge of lighting equipment and the technique of illumination must be supplemented by a specialised knowledge of the requirements and limitations of the photographic process, including the principles of tone reproduction, response curves of different kinds of sensitive surface, colour response, definition, photographic lenses, estimation of exposure.

Lighting for Television

Television lighting is a special technique developed from film-studio practice which in its turn has developed from the art of photographic portraiture. Television can be regarded as a special branch of photography; in consequence the subjects mentioned in the preceding paragraph have their counterparts in Television. A comprehensive discussion of the theory of tone reproduction in a Television system is beyond the scope of this manual, but it must never be forgotten that these highly complex processes intervene between the programme-material in the studio and the viewer watching his receiver.

Television lighting must, therefore, fulfil two distinct and not necessarily compatible functions:

(*a*) the lighting must create the mood, atmosphere or artistic effect required by the production.

(*b*) the lighting measurements must conform to the technical needs of the particular type of camera in use.

In practice these two functions are inseparable; but while the technical requirements vary with the apparatus used, the artistic requirements remain unaltered. This manual, therefore, first describes the basic principles of function (*a*) and later (commencing at Section 5) those of function (*b*).

1.2 Lighting of Solid Objects

Light travels in straight lines. When light falls on a solid object those areas of the object which face towards the light are illuminated while areas which slope away from the light remain dark. If the direction of the light is changed, the light will fall on a different selection of areas. As a result the shape of the object will appear to change. These changes are constantly occurring in nature, but we are so used to them that until we train ourselves to analyse what we actually see, they pass unnoticed. Most people think that lighting out of doors, or in the home, is flat and almost shadowless. This is a psychological illusion, the falsity of which becomes evident as soon as we commence to view faces and scenes through the medium of the camera. Our eyes are naturally adapted to viewing things in the light of the sun, which is usually above eye level. We are, in consequence, accustomed to viewing objects which are lit predominantly from above. When we see a face artificially illuminated from floor level, as in Fig. 1 (iv) facing page 8, it is usually felt to be unnatural and even sinister; this is because the lighting emphasises aspects of the face which are usually suppressed.

In whatever way we light an object, certain parts will be emphasised at the expense of other parts, and in the decision to use one angle of lighting in preference to another lies the basic difference between the Hollywood close-up and the passport photograph.

Although objects in the studio are solid, and the effects of the lighting upon them is due to their solidity, the camera lens converts the scene into a flat picture in which background and foreground are collapsed together, and the dimension of depth no longer exists except as the geometrical illusion called perspective. Areas which in the studio are far behind one another may now appear adjacent on the screen with resultant confusion of identity.

At the receiver, this flat picture is reproduced as a pattern formed by the changes in brightness of the scanning spot as it moves across the screen. Unlike an artist's drawing, there are no outlines in a television picture. What appears in the picture to be the edge of an object is merely the point at which the scanning spot changes its brightness; unless two adjacent objects differ in tone in the studio, the scanning spot will remain the same brightness as it passes across that area of the picture. There is then no possibility of distinguishing any boundary between the objects and the shape is consequently destroyed. A scene in which every area was exactly the same brightness would appear on the screen as a blank.

Ideally, in order to transmit the maximum of information from the studio to the screen, every plane of the scene should have a different brightness from every other plane, but as the total range of brightness tones is very restricted, this ideal can only be partially achieved. In brief, the art of lighting consists in organising the position and relative brightness of the light sources in the studio so that the shape of the objects as finally viewed on the screen will attain the greatest possible significance and programme value. To restore a partial illusion of depth, the lighting is additionally called upon to emphasise the perspective by exaggerating the tonal contrast between near and far objects in the scene, and this is the special function of 'back lighting' as will be further explained later. It is a convention of cinema technique that, starting from the edge of the screen which is dark, foreground objects should be dark in tone, and progressively receding planes should be progressively brighter.

It is important to realise that realistic reproduction in the sense of a re-creation of the original object never even approximately occurs. The brain works by comparing fresh experiences with its stored memories, and making decisions on this basis. A photograph or drawing of, say, a chair, is not really at all like the original chair: children sometimes have great difficulty in disentangling the visual meaning of ordinary story-book pictures because they do not understand the conventional tricks of representation, and the writers have been surprised to note that some adults have similar difficulties with Television.

This again serves to emphasise that in Television we are not, as in the theatre, dealing with real objects, but only with representations of objects. In the process, lighting acquires some of the functions of draughtsmanship.

2. PORTRAIT LIGHTING

2.1 Illumination

In this section we begin a survey of the principles of portrait lighting. These basic principles are deducible from the geometrical properties of light rays and remain the same, whatever the technical apparatus used for reproduction.

Let us commence by distinguishing between 'soft' light and 'hard' light. The theoretically ideal source of light is a point which has luminosity but no magnitude. Light from such a point proceeds outwards along straight lines in all directions equally, obeying the Inverse Square Law. An object placed in the path of the light blocks it off completely and is said to cast a shadow or black area in which there is no light. A point source thus produces a 'hard' black-and-white effect, with a geometrically precise shadow.

Now suppose we take an area 2 ft square and place in it a very large number of point sources. If we hold an object such as a penny in front of this luminous area, obviously every point source in the area will form its own shadow of the penny; there will, therefore, be a very large number of shadows all over-lapping, but so much light will get past the penny that for all practical purposes the shadows are cancelled out. Such a luminous area is said to form a shadow-less or 'soft' light. But note that if we put up an object nearly the same size as the luminous area, we shall block off most of the light and a noticeable, though not well-defined, shadow will occur. Conversely, if we were to take our luminous area a long way from the object, it would behave more nearly like a point source. The sun, for example, is nothing like a point source in reality, but it gives a hard shadow simply because it is so far away that only parallel rays of light reach us.

The difference between a 'soft' light and a 'hard' light is really one of relative size. A source which is very small compared to the object which it illuminates will produce a hard shadow, and conversely. It is thus impossible to turn a spotlight into a 'soft' light by putting diffusing gauzes over it. Even if the gauzes are perfectly efficient in scattering the light evenly, the total area of the source remains small compared to the scenery and furniture in the studio. Again, the smaller the area of a bank of soft light, the more likely it is to produce visible shadows.

In practice, gauzes produce a marked diffusing effect on a bare bulb. With all lamps using lenses, however, the effect of a gauze is mainly to reduce the intensity of the light, or to even out small irregularities in distribution.

Reference has been made to the Inverse Square Law, which states that the illumination of an area is inversely proportional to the square of the distance from the source of light. Many text-books omit to emphasise that the law only applies to an unmodified point source; it does *not* apply to any kind of lens system, and it does not apply directly to a soft light which, as explained above, can be considered as an infinite number of point sources side by side. In practice, this means that a lens spot can be operated efficiently a long way from a scene, whereas open floods or 'broads' containing a single bulb obey the law, and are ineffective unless relatively close to the object they are illuminating. Large area sources have a peculiar law: an object along the centre line of a soft light source receives approximately the illumination that it would receive from a point source whose distance away was the distance between the object and the edge of the soft-light source.[1]

From the practical point of view, the Cosine Law is particularly important. It states that the illumination of a surface is proportional to the cosine of the angle of incidence of the light. Put into plain language, this means that one cannot efficiently illuminate a caption board or a backcloth with its edge towards the source of light. Nevertheless, it is often a great temptation in a crowded studio; it looks so reasonable to light a backcloth by a row of floods immediately along its top edge, or a cyclorama by lengths of footlight along the bottom. Sometimes there are particular reasons for using such an arrangement; nevertheless, the efficiency is very low, and no flat surface can be evenly lit in this way.

With solid objects, it is the operation of the cosine law which produces a gradual reduction of illumination on surfaces which curve away from the light, and this is an important factor in recognising the shape of such surfaces. Twilight on the earth is the point at which the sun's rays become tangential to the earth's sphere, and the cosine of the angle of incidence rapidly descends to zero.

To understand the following paragraphs it is essential to view an illuminated model head. The photographs in Fig. 1 (facing page 8) show some of the effects described, but the student should at the first opportunity set up an actual model and see for himself what happens. He should also bear in mind a point that cannot be shown by illustrations: that an actual television production involves constant movement, so that all the effects are transient.

2.2 Experiment in Portrait Lighting

(1) Set up a model head on a table, or stand, about 4 feet from the ground, and direct a small spotlight on to it at about the same level. Now walk all round the head and observe that in general it is roughly spherical, and that half of it is illuminated, while the other half is dark.

(2) Put the head close to a wall and arrange the spotlight so that the head's shadow falls on the wall. Now put your eyes as close to the spotlight as you can and look along the beam. You will find that the shadow of the head is practically hidden from your view by the head itself. If you could actually look down the centre of the light beam, your eye would be able to reach only what the light reaches, and the shadow would be quite invisible, i.e. the lamp can never see a shadow anywhere. Moreover, the planes of the face are nearly all equally illuminated, so that the result is flat and lifeless. See Fig. 1 (i).

As you move away from the lamp the shadow begins to come into view. Also, the dark side of the head begins to be visible, so that when you are at right-angles to the lamp, the head appears half-light, half-dark.

Note also that what has been said about the large shadow of the head applies equally to small shadows such as the nose shadow, shadows of the lips, and the miniature shadows caused by roughness of texture. Accordingly, replacing our eye by the camera lens, we can state the following rule: the degree of shadow, modelling and texture visible to the camera is at a minimum when the camera lens coincides with the light source, and increases proportionately as the angle between the camera lens and the light source increases. In general, the most satisfactory result (i.e. the most information about the shape of the object) is secured when this angle is about 45 degrees. The angle must of course be adjusted in practice to suit the object, *not* to comply with this statement. In film and photographic work a small 'eye light' is sometimes fixed on the camera close to the lens. The object is to reflect a sparkling catch-light from the subject's eyes without affecting the modelling. In Television, a larger diffused light is often used close to the lens, to lift the shadows caused by high-angle lighting and soften harsh lines in a close-up. Both these lights are, of course, additional to the main lighting.

(3) Stand directly in front of the model head with the spotlight beside you at an angle of about 45 degrees with your line of sight. See Fig. 1 (ii). Note that the side of the face nearer the spotlight is bright, while the opposite side is partially in shadow. The nose is also casting a considerable shadow. Now get someone to move the head about, as if it were a living person. As the head turns from side to side you will observe that the nose shadow alters in length, and as the nose turns away from the spotlight the shadow becomes so long that it joins up with the shadow on the darker cheek. As the head nods, the nose shadow moves up and down. Remember that all your subjects will be *moving* all the time. You will not be popular with the lady announcers if you give them long, wobbling nose-shadows!

Now move the spotlight towards you slightly. You will see that the line formed where the light and shadow meet down the model's darker cheek has altered its position. The nearer you bring the spotlight towards you, the further back this line goes, and the more cheek you see. It is almost as though you were cutting cross-sections of the face. Thus, by adjusting the angle of the light, you can decide which part of the face you wish to show or hide.

Observe that in Fig. 1 (ii) the illuminated side appears wider than the dark side. The reason for this is that although in reality the side of the face from cheek-bone to ear is receding from the lens, in the flat reproduction it is impossible to perceive this unless there is an alteration in tone. In a black area there is no information at all. On the dark side of the face, therefore, the information stops where the light stops. On the bright side of the face the lighting reaches right back to the ear, and consequently the receding part of the face gets added to the cheek as extra *width*. This is illustrated very well by comparing Fig. 1 (ii) with Fig. 1 (i). In Fig. 1 (ii) the cheek and eye on the dark side of the face appear quite small; in Fig. 1 (i), the apparent length of the eye has been nearly doubled by merely moving the light to a frontal position. As few people have faces with perfectly equal halves, we can appear to improve the symmetry by putting the light on their narrow side.

(4) Try the effect of altering the height of the lamp. As the same rule about the angle between lens and lamp applies both vertically and horizontally, we can further adjust the modelling by placing the lamp higher or lower than the camera. An example of overhead symmetrical lighting (often called 'Marlene Dietrich' lighting) is shown in Fig. 1 (iii), while lighting from underneath the face produces a devilish 'footlight glare'. See Fig. 1 (iv).

As the lamp is raised, the horizontal surfaces of the face—such as the cheek-bones—are accentuated, but the eye sockets become darker. Conversely, a lamp on the floor illuminates the underside of the cheeks and the eye sockets. A small lamp in this position is often useful as a supplementary to improve faces with deeply recessed eyes, or heavy creases on each side of the nose. It should not be forgotten that a certain amount of light is scattered upwards from a light-coloured floor, producing a similar effect to a footlight.

The student is advised to arrange two spotlights of equal intensity, one on the floor, the other as high as possible, and see how completely the face is altered in appearance by switching them alternately. Note that a lamp on the floor may cast shadows of the subject's hands, and even parts of the camera, on to the artist, and should be used with great caution on an actual production.

(5) Except for very harsh and dramatic effects, the shadows in a portrait should always contain detail. When we have decided on the optimum position for our frontal light as described above, the shadows will probably be much too dark, as shown in Fig. 1 (ii). Before the portrait can be considered satisfactory, additional lighting units will be needed to soften the contrast and improve the modelling in areas which the frontal light cannot reach. In order to ensure a clean, definite result, free from confusing shadows and with properly controlled tonal gradations, any extra lighting units must be subsidiary to the main frontal light which is, therefore, called the 'Key Light'.

The first supplementary light required is a soft 'filler' light placed on the opposite side of the camera to the key light. The brightness of this filler should be adjusted (either with a gauze, or by taking it further away from the subject or by turning it slightly) until the shadowed side of the face shows sufficient detail. Fig. 1 (v) shows the same key light as Fig. 1 (ii) with a filler added. This lifts the shadow on the model's left cheek without casting any further shadows. A well-diffused light is essential here, otherwise it will compete with the key light and produce an extra nose shadow. One nose shadow is permissible, even desirable. More than one is most unflattering. See Fig. 1 (vi).

(6) The front of the face is now reasonably well lit, but the back of the head remains dark. From the point of view of the camera, what can be seen of this black area appears as a black outline round the head, giving the face rather the appearance of a mask. This effect is much accentuated with certain subjects so that the face may appear stuck on to the background. We therefore place a 'back' light to illuminate the back of the head. This lamp, which faces towards the camera, must be arranged above the head so that the light does not enter the lens. Try the effect of switching the back light on and off; observe that the apparent length of the scalp from front to back is noticeably increased as the back light is switched on. The back light also adds sheen to the hair, and puts a luminous line round the head, which separates it from the background. Compare Fig. 1 (vii) with Fig. 1 (i).

Move the back light to three-quarter back and notice how it accentuates the side of the face. As additional modelling can be produced by this means, two three-quarter back lights are sometimes better than a centre back light. See Fig. 1 (x).

Care should be taken to see that the back light is not too high above the subject. Try this, and note that with a very steep back light, if the head is tilted back slightly, the tip of the nose becomes illuminated, with very ugly results. See Fig. 1 (viii). A diffused filler was added to give facial detail in this photograph.

Anyone working or demonstrating from behind a table should never be lit with a direct back light, as the hands would be shadowed by the head.

The completed portrait, using a key light at about 35 degrees with the lens (in both horizontal and vertical directions), together with a filler and back light is shown in Fig. 1 (vii).

(7) We have so far considered the lighting of a head, floating—so to speak—in empty space. In practice, every portrait must appear against some kind of background, and as there is an almost infinite range of possibilities, each case must be treated individually. It is a good rule, therefore, to treat the background as a separate item with its own lighting, and to do this properly the background must be sufficiently far away from the artist to eliminate unsightly shadows cast on it by the portrait lighting. (This is not always possible in the studios.)

The two simplest backgrounds are obviously a black background and a white background. With reference to the BBC Television system, this means a background of such an intensity that it is reproduced either at black level or at peak modulation.

Suppose we place our illuminated head against a black background, then the camera equipment will reproduce the black background at black level, while the highlights on the face will be reproduced at peak white. The darker parts of the face may take up any tone between peak white and black, but obviously cannot be darker than the background.

Similarly, if we use a white background, this will be reproduced at peak white, and the brightest parts of the face will take up intermediate tones. We can therefore say that the ratio between the brightness of the background and the brightness of the face determines whereabouts on the scale of greys the face tones are placed. By brightening the background, we tend to darken the face and make the face shadows blacker; by darkening the background we tend to whiten the face and make the face shadows less deep. (Note: These effects are accentuated and complicated in Television by the operation of d.c. restoration. In this section we are confining discussion to the purely photographic aspects.)

It is important to realise that the question of intensities is a relative one; thus, if we were to halve the brightness of all the lamps in our portrait set-up, the brightest part of the picture would still appear as peak white on a receiver, provided always that the camera receives enough light to enable it to function correctly. Viewers and even producers have been known to complain that the pictures on the screen were 'too dim'. This result can only be produced by insufficient amplification at some point in the electronic chain and has very little to do with the overall brightness of the studio lighting.

Further notes on the treatment of studio scenery will be given in a later section. The basic requirement is to separate the figure of the artist from the background and enhance the illusion of depth. The possibilities of graduating the brightness of the background to emphasise particular parts of the subject should not be overlooked. It is a generality of film technique to illuminate sets so that the walls decrease in brightness at about shoulder height. By doing this, the head of a standing artist is seen against a darker area, and the body against a lighter area. There is, of course, no fixed rule about this.

What has been said about backgrounds also applies to the clothes worn by artists. If these are too light or too dark, the artist's face is adversely affected. It may sometimes be possible to light the clothes separately from the face.

(8) We have now completed our survey of basic portrait-lighting technique, and see that in its simplest form it consists of four elements:

(*a*) Key light,
(*b*) Filler light,
(*c*) Back light,
(*d*) Background light or lights

together with supplementary lights such as those described in paras. (2) and (4). Observe that by subtle adjustment of these four elements, a corrective effect can be produced on the face, tending to bring it nearer to the accepted ideal of beauty. The Make-up Department are trying to do the same thing, and it is important to realise that to some extent light and paint are interchangeable in a monochrome picture. The lighting and make-up can therefore cancel one another out if they are not in accord. The make-up affects the lighting in two distinct ways. Firstly, the relative tones of parts of the face may be altered to correct the modelling. Secondly, the overall colour or tone of the face may be altered so that the ratio of the average face tone to the background tone is changed. As already explained, this ratio deter-

Fig. 1. An Experiment in Portrait Lighting

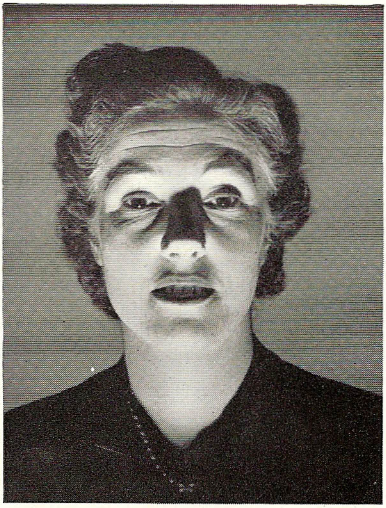
(i) Single lens spot close to camera, slightly to the left and above camera

(ii) Single lens spot to left of camera at 45° horizontal and 30° vertical with camera lens

(vii) Lens spot on camera left at 35° horizontal and 35° vertical with camera lens. Diffused filler on camera right. Spot back light facing camera and suspended above and behind model

(viii) Lens spot directed vertically downwards from above model's head. Diffused filler as frontal light

(iii) Single lens spot above camera at 60° vertical



(iv) Single lens spot on floor in front of camera

(ix) Two lens spots, one on each side of model at 90° with camera lens

(x) Diffused open-type lamp near camera. Two lens spots as three-quarter back lights facing camera

Fig. 1. An Experiment in Portrait Lighting

(v) As ii, with addition of diffused open-type lamp on camera right

(vi) Two lens spots, one on each side of camera

(xi) As x with right-hand lens spot only

(xii) As x with no lens spots

mines what tone the face will take up in the final picture, and it has been known for the Make-up Department to alter this ratio accidentally while attempting merely to improve the modelling. The lighting engineer should make sure that any corrective lighting he may do is adjusted to suit the artist with *completed* make-up and correct costume, and not as he may appear on rehearsal. The panchromatic film and some studio-type television tubes favour the red end of the spectrum. This means that warm colours tend to be reproduced whiter than cold colours, so that in general the camera accentuates the face with respect to the background and costumes—a very desirable feature from the practical point of view. For this reason the background-foreground balance is closely related to the colour response of individual camera-tubes. Incandescent lighting is very red and favours the face, while bluish light such as the high-pressure mercury lamps tends to leave the face dark, especially the cheeks and lips, and favour the scenery. Mercury lighting must be used very cautiously for this reason, especially as frontal lighting.

It should be noted that the tonal gradation of the face reproduced in monochrome should largely represent *shape*, not colour. Any colouring of particular areas, such as the cheeks, tends to alter the structural appearance of the face without conveying any impression of colour. In the same way, the colour of scenery can confuse the shape in reproduction.

2.3 Multi-camera Technique

We are now in a position to consider the application of the above principles to a multi-camera technique.

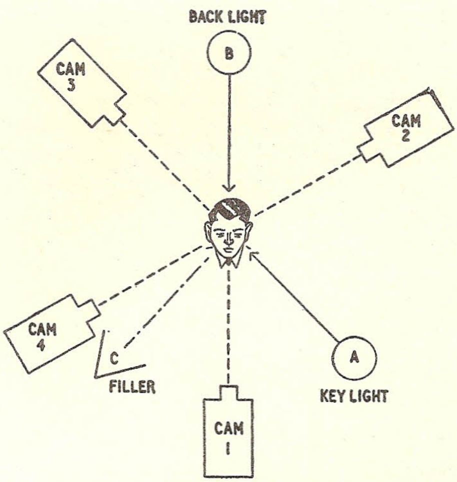


Fig. 2. Three-point Lighting

Let us return to our model head, set for a conventional photographic portrait. Fig. 2 shows that the three lamps, key-light lamp A, back-light lamp B and filler lamp C, are making angles of 120 degrees with each other, approximately. This arrangement is referred to in later sections as 'three-point' lighting. Up to now we have been imagining ourselves standing in the position marked in the diagram as camera 1. If we walk all round the head we shall find that it is reasonably well illuminated on all sides. Suppose we turn the face towards camera 2: then instead of the key light and the filler, the face is lit more or less symmetrically by lamps A and B. This produces a curious effect in that the two sides of the face and the sides of the nose are brighter than the centre parts. See Fig. 1 (ix). Also, if the lights are high up, the eye sockets will be dark and may even appear as two blank, black circles surrounded by a bright line formed by the jutting cheek bones. This result, which looks peculiarly horrible on the screen, is known colloquially as a 'pair of spectacles'. A small rotation of the head towards either lamp may produce the effect of one eye being lit, while the other remains black; this may happen when lighting pianists who turn away from the keyboard to speak. The student should try deliberately to produce these effects on the model, note carefully the angles at which they appear and observe how far they can be avoided by accurate placing of the lamps. Fig. 2 must, of course, be regarded as a purely conventional representation. Considerable re-arrangement of the lamps will be required to reproduce the effects shown in the photographs, since the results depend on the facial structure of the individual model. The height of the lamp is an important factor, and this in practice is often determined by the architecture of the studio and set. It is therefore interesting to set the lamps on the model at the angles they would actually be in relation to a real artist in a full-size set and note the different effects which automatically occur when using either overhead lighting or floor lighting.

Now turn the head towards camera 3. This is similar to the previous situation except that lamp C is less hard than the others. Lamp A is now acting as a back light.

Going still further round, to camera 4, we get a rather flat picture with the lens next to lamp C, but the overall result is quite good because the two other lamps are acting as three-quarter back lights. See Fig. 1 (x).

It is rather interesting at this point to turn the head sideways. As plays consist largely of conversations, a great number of profile shots occur. We can see that lamp A, acting as a three-quarter back light, gives a bright edge to the profile, so that the side of the face near the camera tends to be darker than the further side. See Fig. 1 (xi). Now switch off lamp A and note that we revert to a black edge, which is, of course, produced by the operation of the cosine law on the parts of the profile which are tangential to the light. See Fig. 1 (xii). By choosing a suitable position for the back light, we can have either a light or dark profile, as required. The arrangement detailed above using several cameras would, of course, never occur in the studio except on a large scale. If we imagine the area indicated in Fig. 2 expanded into a full-size set including two or more artists facing in opposite directions, we see that our original concept of portrait-lighting technique must be replaced by large scale 'three-point' lighting in which the artists can move about freely and be examined from all angles, rather as in a circus-ring. In these conditions, any one of the three lights may be either a back light or a key light depending on the camera being used at the time. It follows that the angles of the lamps must be adjusted so that, as far as possible, the unsatisfactory positions for the artist occur in long shots, and the close-ups coincide with optimum portrait-lighting conditions.

2.4 Avoidance of Microphone-boom Shadows

We must now consider how to avoid shadows of the microphone boom.

Considering our portrait set-up again, it is clear that if a microphone stand is set in front of our key light, the shadow will be thrown forward on to the artist. The obvious place for the microphone is next to the filler light, so we deduce our first rule: the key light should always be on the opposite side of the camera to the microphone stand. The same rule applies to the large microphone boom, except that since we are dealing with large areas, we modify the rule to read: the main frontal light should be on the opposite side of the set to the microphone boom.

From the point of view of the boom operator, studio lighting falls into three main groups:

(*a*) Suspended banks or floods. As these do not cast observable boom shadows, we can neglect them here.

(*b*) Overhead spotlighting. By this we mean 'hard' lighting units which are either suspended or fixed to a gantry considerably higher than the microphone boom.

(*c*) Floor spotlights. By this is meant 'hard' lighting units on stands on the studio floor, of a height comparable with the boom arm. Floor floods are also used, but the shadows are negligible.

The usual position for the microphone (on the end of the boom) is 2 ft to 3 ft in front of the artist and just above the top edge of the camera's line of sight. As the camera tracks back, the microphone has to be raised.

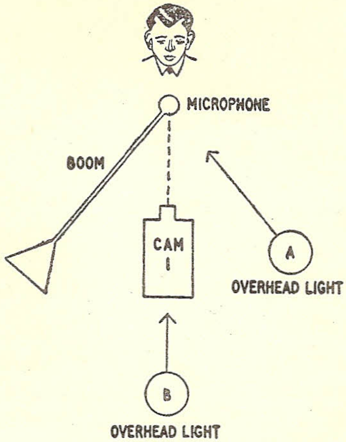


Fig. 3. Illustrating Basic Boom-shadow Rule

Fig. 3 shows an artist in front of the camera. Now suppose we place a light immediately behind, and looking over the top of the camera, at B. Obviously, the boom shadow will be thrown forward on to the artist. If on the other hand we light the artist from point A, the boom shadow will be thrown to the left of the camera, out of shot. We can therefore state our basic boom-shadow rule: the distance between the boom shadow and the artist is proportional to the angle between the lamp and camera lens; consequently, the wider the angle between lamp and lens, the less likely we are to see the boom shadow. But also, the wider the angle becomes, the longer the nose shadow and the harsher the facial modelling. We must therefore find a compromise between the appropriate degree of modelling and the difficulties of the boom operator. We now encounter another difficulty. The high-velocity type camera tubes require a relatively large amount of frontal illumination. According to the cosine law, the greater the angle of incidence of the light on the object, the less will be the illumination. There is consequently a direct relationship between the boom shadow and the amount of 'hard' frontal light which can be placed on any acting area. The easier we make it for the boom operator, the more difficult it becomes for the vision-rack operators, and vice versa.

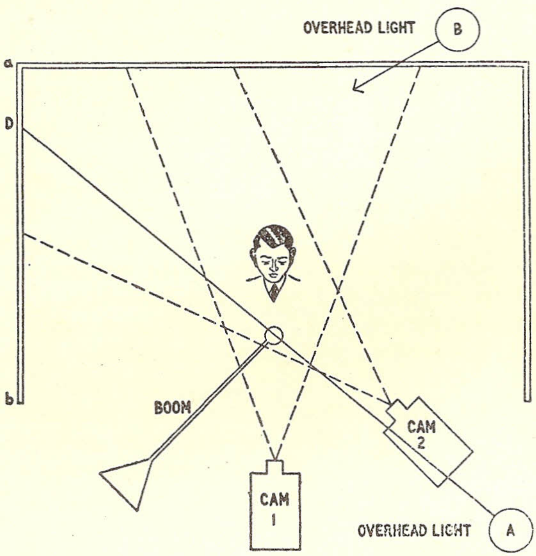


Fig. 4. Avoidance of Microphone-boom Shadows on Walls of Set

Fig. 4 shows the artist surrounded by three walls. As before, he is lit from point A (overhead light). The boom shadow will be in advance of, but much lower than, the boom; and in a close-up, when the boom is near the artist, the shadow may fall on the floor, where it is usually negligible. If the camera tracks back and the boom consequently rises, or if the walls are very close to the artist, the boom shadow will be thrown on to the wall, and is shown in the diagram at D. This is still perfectly satisfactory, since it is out of shot of camera 1. But now suppose the producer introduces a second camera, as shown; lamp A, camera 2 and the microphone are all in a straight line, and the shadow will be visible.

A solution would be to tip down or shutter off lamp A, so as to cut off the light from the wall at D. This would leave the artist still illuminated, but if he moved towards the wall (*ab*) he would walk out of the light. He would then have to be re-lit from the back of the set by a lamp at B.

Fig. 5 shows what happens. Camera 2 has now moved towards the wall (*ab*) to view the artist there, who is now lit from lamp B; observe that the original frontal light A is right behind the camera and therefore, even apart from the boom-shadow difficulty, is less suitable from the lighting point of view than lamp B, which is now at a more satisfactory angle with the lens. The boom has moved across the set to the artist, and the shadow is now outside the field of the camera, at E. We may deduce from this illustration that frontal lighting tends to give most trouble when several cameras are being used and, as a matter of routine, every possible opportunity should be taken of lighting from the back of the set.

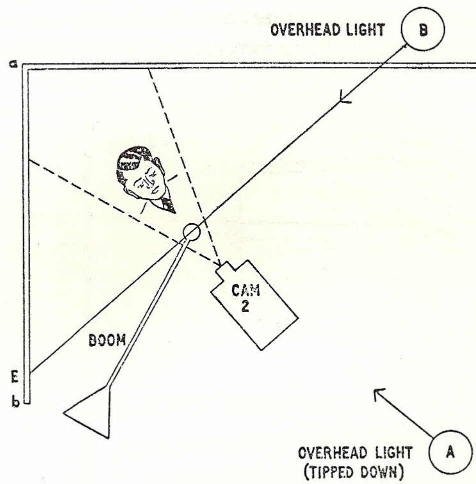


Fig. 5. Illustrating an Advantage of Lighting from Back of Set

The above lighting suggestions are effective only if the boom keeps following the artist all the time. Many difficult situations arise in practice because, by making a sudden cut to another camera, the producer can out-run the boom operator. A shadow of the boom in process of chasing the artist may then appear, although the lighting will in fact be perfectly correct, once the boom is in position. It may be taken as axiomatic that with hard frontal lighting, arranged as described above, only one boom can be operated successfully at the same time on the same set, and as the whole of the lighting has to be pre-planned with reference to the position of the boom in the studio, it is very important to ensure that the position of the boom has been decided finally by all concerned before lighting takes place.

Turn again to Fig. 2 and examine the position marked camera 4. There is a soft frontal light near the lens, with two three-quarter back lights. See Fig. 1 (x). If this arrangement is extended to a full-size set, using large banks of soft lighting, we have what appears to be an ideal solution to the boom problem. Since there is only soft frontal light the boom shadow is eliminated, while modelling is supplied by hard light from the back and sides. This arrangement is the traditional set-up for Television, often referred to in literature, but until recently seldom practised. It suffers from several drawbacks. In the first place, except for very special shows like ballet, or on very small sets, it is difficult with soft light or floods alone to get enough frontal lighting to satisfy the high-velocity type camera tube. On this score the method is more satisfactory with the more sensitive Orthicon-type cameras. The second drawback is that the light is scattered indiscriminately over the whole area, so that control of the contrast between faces and background becomes difficult. This feature again commends it to Orthicon-type cameras, where the contrast range must be drastically limited, but with high-velocity type tubes the general result is to produce a very flat picture, with rather poor facial modelling.

When lighting for high-velocity tubes, it is often best to employ several kinds of frontal lighting simultaneously. For example, high-angle overhead lighting can

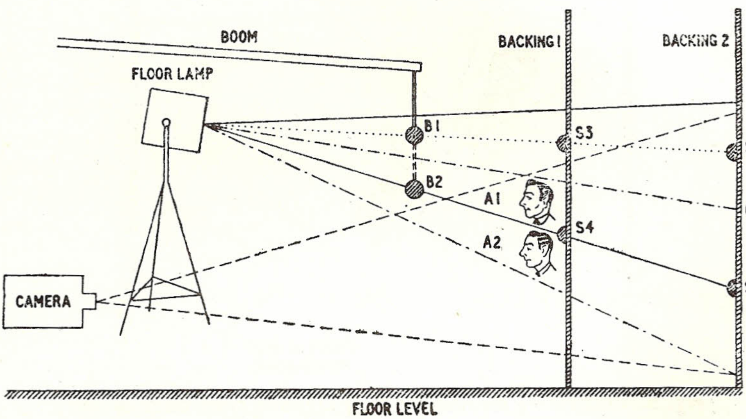


Fig. 6. Effects of Floor Lighting

be used if floor lighting is added to counteract the rather drastic modelling, while suspended soft light can be added as a general filler. As a result, the setting of individual lamps tends to be somewhat less stringent and it is easier to find a compromise between the numerous divergent factors. With this system the frontal light, although mainly supplied by hard light, can be regarded as general illumination, so that the set-up falls into the category described above. By increasing the amount of soft light overhead, it is sometimes possible to do away with hard overhead frontal lighting; then it is possible for more than one boom to be used on the same set.

We must now consider the effects of floor spotlights on the boom. Fig. 6 shows a side view of an artist A against backing 1. The floor lamp, which is close to the camera, casts a shadow of the boom B1 on the the backing 1, at S3, where the camera cannot see it. This is satisfactory. But suppose the backing is further away, at backing 2: then the shadow will appear at S1 and will be seen by the camera. We therefore tip the lamp down so that the light skims over the head, A1, leaving backing 2 dark above the point C. S1 therefore disappears. But suppose the artist sits down to position A2. The boom follows to B2, and immediately the shadow reappears in shot at S2. Note that this time it would appear on backing 1 at S4 which is also in shot. The same rule about the angle between light and lens applies, as in the previous section, but the restriction of space on the floor often makes it difficult to place a floor lamp in a satisfactory relationship to the camera. Moreover, if the camera goes far into the set, it will over-run the lamp, and the artist will be covered in camera shadows. Despite these difficulties, floor lighting can often be used where overhead lighting would be disastrous. This particularly applies to small sets where the artists work close to the walls. As can be seen from the diagram, the close backing slightly favours the floor lighting, while the reverse is the case for overhead lighting.

The diagrams shown are intended to indicate only basic principles. In a large production we are faced with the task of adapting our theoretical ideas to the actual structure of the scenery and groupings of the characters, which will be individual to each show. Even a constantly repeated programme may be lit quite differently by each individual member of the lighting staff. The student must decide for himself which of the many solutions to a problem he prefers and should, by applying the basic principles, endeavour to build up his own methods of dealing with each assignment.

3. LIGHTING OF FULL-SCALE PRODUCTION

What we have discussed so far has been labelled 'Portrait Lighting'. In a full-scale production we have to deal simultaneously with four aspects of lighting:

Technical Lighting

Whatever the artistic effects we aim to produce, the position of the lamps in the studio, the brightness, contrast ratio and evenness of the illumination must be such that the cameras will work efficiently in all parts of the set required by the producer, and that the boom operator's skill is not overtaxed.

Portrait Lighting

As already explained, portrait lighting in itself is designed to give a photogenic interpretation of a face. In films all close-ups of stars are portrait-shots individually lit and tailored to suit that particular face. This is only possible in television in a fixed shot of a single artist: nevertheless the primary function of the acting-area lighting must be to give an acceptable rendering of the faces.

Environmental Lighting

Using the basic methods of portrait lighting, we are here attempting something more creative; we are helping the scene designer to manufacture a place that does not actually exist, but which we must persuade the audience is real.

Dramatic Lighting

As in the theatre, the dramatic emphasis that lighting can give is tremendous. In real life the lighting is fortuitous, whatever awful event may be occurring, but in a play we can to some extent make the lighting appropriate not only to the scene, but to the mood of the drama. Often even an individual performer such as a pianist can be lit in a dramatic or imaginative manner that much enhances the interest of the picture, but is in no way naturalistic. We can, however, say that the emotional effect of any kind of lighting on the audience is governed by their previous experience of lighting effects in real life.

When lighting any production, the best way to start thinking about it is to imagine what the scene would look like if it were a real place. We are so used to seeing daylight coming through the window, or the shaded hanging bulb in the living-room, that it is difficult to realise that these 'natural' lighting devices have exactly the same effects on the human face as the directed lighting described in Section 2.2 with the disadvantage that the angles are often extreme.

Even out of doors, natural sunlight is usually much too hard for good portraiture, as can be easily seen by looking at close-ups on newsreels. It follows that a strictly accurate reconstruction in the studio of 'natural' lighting effects, even if feasible technically, would not be acceptable to the viewers. Nevertheless, it is essential to give atmosphere or 'flavour' to a production. We must therefore effect a compromise. One way of doing this is to light the acting area and actors with three-point lighting arranged to give the best possible compromise for close-ups, and then to light the walls of the set quite separately to produce a convincing illusion of environment. It may be taken as an axiom that the viewer is primarily interested in a good rendering of the actors' faces, and will not expect to see any naturalistic lighting effects unless the source of such light appears in the shot. For example, if an actor walks close to a brightly lighted window, the audience will expect to see that the side of his face near the window is brighter than the other side. On the other hand in the middle of the set, with the window out of shot, the direction of lighting is immaterial unless attention is specially drawn to it by dialogue. It is thus possible to maintain our conventional three-point lighting while supplementing it at appropriate points to give an illusionary reality.

When dealing with background lighting every opportunity should be taken to reinforce the architectural illusion of the scenery. Textures, angles, mouldings, arches, steps, all require lighting so that their three-dimensional solidity is enhanced. We are accustomed to associate solidity with a heavy cast shadow. Even a cardboard cut-out may be made to cast such a shadow and will be immensely more impressive as a result.

While a simple scene could be lit by a system of lamps corresponding to Fig. 2 on a large scale supplemented by background lighting, in practice most scenes tend to split up into two or three smaller acting areas, so that more in the way of individual treatment of camera-shots is possible than is apparent from theoretical analysis. The many harsh results illustrated by the experiments in Section 2.2 can be modified if they become awkward, by adding extra lamps and by a host of minor adjustments during camera-rehearsal. The student may find difficulty in analysing an actual studio lighting set-up for this reason, as by the end of the rehearsals every lamp has several functions and its precise significance is unexplainable unless one follows the whole production through, shot by shot.

The above description may suggest that something very complicated is required, but the way to tackle the situation is as follows:

The student should regard it as an essential part of his training to find out:

(*a*) What people and architecture actually look like under different kinds of lighting in nature.

(*b*) What these things look like when reproduced by newsreels and television outside broadcasts under natural lighting; e.g. Trafalgar Square on election night.

(*c*) What similar scenes look like as studio shots in feature films.

For portraits, a book of still-photographs of film stars is very useful.

By these means the student will build up a series of mental pictures of what things ought to look like on the screen, then in actual studio work he should initially forget all about art and the theatre, and concentrate on overcoming the technical problems presented by cameras and boom. As the rehearsal proceeds he will see for himself where his lighting succeeds or fails in looking realistic and will make appropriate adjustments. To give some idea of the practical methods of applying the principles discussed above, an actual studio lighting plot is analysed in the Appendix.

As we have seen, adjustment of the relative positions and brightnesses of the components of a lighting scheme alters the degree of shadow and contrast range. A famous film director, asked to explain what his job consisted of, replied, 'Trying to prevent the director of photography from lighting my comedies so that they look like Hamlet'. *High-key* lighting, in which smooth, bright, low-contrast effects are used, is appropriate for comedy, while *low-key* lighting, rich in blacks and heavy shadows, sets the mood for drama. In addition, we can have the faces lighter or darker than the background, or with a light or dark edge to the profile. Each of these results can be used to emphasise the atmosphere or period of the scene.

To assist the student to develop his observational ability, below is a list of questions which he should try to answer by *looking* (it may help to carry a monochrome filter in the pocket):

(1) What do peoples' faces look like in a room lit by: (*a*) one window; (*b*) two or more windows? Is there a pronounced nose shadow, or is the lighting soft and diffused? How are the walls lit? Do people cast shadows on them?

(2) What does a face look like in a room lit by the conventional overhead light? By a candle? By a reading lamp? Do any of these lights cast shadows of people, or patterns, on the wall? Which do you think is the most flattering light for a dinner party?

(3) What does a face look like in moonlight? Does moonlight cast a shadow, or is it diffused? What happens to the sky?

(4) How many shadows are there of a man walking up the aisle of a cathedral in full daylight, with sunshine streaming through the windows?

(5) How many nose shadows has a man sitting in a tube-train?

(6) What kind of effect is used on the cinema screen to depict characters in a

night scene or a dark tunnel? (This question must be answered by careful study of feature films in the cinema.)

(7) What do peoples' faces look like in sunlight? Why does sunlight look like sunlight, and not moonlight? (Apart from the intensity or colour, which are not apparent in a photograph.) What length of shadow is cast by sunlight at noon?

(8) When standing under a street lamp, can you see the shadow cast by the neighbouring street lamp?

(9) What happens in films when a character turns a practical lamp on or off? (Answer as Question 6.)

To avoid puzzling the reader, it should be made clear that these are not examination questions and have no hard-and-fast answers. The solutions can be found only by collecting real-life samples.

In producing naturalistic effects such as those referred to above, there are several technical points to be remembered:

We are dealing with a graphic art, consequently white paper, white chalk, white paint, are exact equivalents for areas of white light. A table lamp with a white paper shade will look lit all the time whether there is a lamp inside it or not. To look right, the shade must be of such a colour that it is a darkish tone when not lit, but when switched on goes up to, or nearly to, peak white.

At no time on any set, or any part of a set, must there be no light, whether the camera will accept it or not. Every shot must contain a peak white, even if it is supposed to be night-time. This is another way of saying that night or moonlight effects are produced by an artistic illusion. Find out how an artist would depict a moonlight scene in a black and white magazine illustration. Mere dimness on the screen is meaningless. To take a simple example, a 'sunlight' scene might be lit by a strong frontal light, with very little back light, the peak white being taken by the face. Suppose we reverse the lighting? We now have a strong back light, with very little front light; the face goes dark, the peak white is now taken by a halo round the hair; the result is a 'moonlight' scene. What we have done is to alter the pattern of black and white in the final picture, though the relative brightnesses may be identical.

The same thing must be done when somebody switches off the 'domestic lighting' in a drawing-room scene. In the theatre it is often sufficient if the scene goes dim, as in real life. In the Television studio we must immediately replace the 'domestic lighting' pattern with a fresh pattern, i.e. we must alter the lighting so that the room now appears lit by firelight, moonlight, or light streaming through the open door. No amount of juggling with the controls on the camera equipment can produce the right result, except as an adjunct to an actual change in the studio lighting. See Section 5.1.

It should be remembered that the above remarks apply to the contents of the picture frame at the moment of change. If a practical light is switched on out of shot, the audience cannot know anything about it, and the same applies to any other kind of lighting effect. This is a very important point, because producers sometimes insist on an elaborate lighting effect and then take a shot which renders it either invisible or inexplicable to the viewers. Whenever a special effect of any kind is asked for, be it firelight or lightning flash, the student must learn to think firstly, 'What will the camera be looking at when the effect occurs?' and secondly, 'Precisely what alteration in the six or seven tones of grey at my disposal can be made to give the illusion asked for?'

The question of lighting perspective has already been referred to in Section 1.2. Let us suppose we are looking through a door into what we assume to be another room. If this area is dark we shall not be able to see much through the door, and our eyes focus on the door frame. But suddenly the area beyond is illuminated and we see it is not a room at all, but a passage 100 yards long. Now, unless the lighting reveals this fact to us, we have no means of knowing what is beyond the door. Where a black area begins, information stops. Just as brightness in a Television picture behaves like white chalk, so darkness behaves like black velvet. For this reason, even in a night scene, some illumination is advisable behind a window to give depth, while perspective shots like a series of arches or rooms should be lit to appear progressively brighter the further away they are from the lens.

Coloured light, or coloured filters over the camera lens, favour objects of the same colour as themselves and darken other objects. Although this has as yet been little exploited in Television, due to lack of sufficient sensitivity, it is likely to become increasingly important in the field of special effects. The *Samoiloff* effect, in which scenes and people can be made to change their colour and shape by altering the colour of the lighting, has been successfully used in Television productions. There is also a large field for trick effects, using ultra-violet lamps and fluorescent paint. The relevant data will be found in books on stage lighting.

4. THE HUMAN EYE

Since the human eye constitutes the final link in the television chain, it has seemed advisable to include a short note on the process of vision. However, as the actual mode of operation of the eye is still the subject of research and controversy, this section is designed to stimulate interest in the subject and should not be taken as a scientific statement of facts.

A diagram of the eye shows that it is a nearly spherical ball with a transparent window at the front. Mounted, as it were, on gimbals, this ball can be turned at will towards an interesting spectacle. In the forepart of the eye are several structures forming a refracting system, including the so-called 'crystalline lens', which can be altered in focus as required. The refracting system projects an inverted optical image on to the rear part of the eye, which is lined with a transparent layer of nerves called the retina. The tips of these nerves, called the rods and cones, are sensitive to light. They face *away* from the lens, so that the light has to pass through the thickness of the layer before reaching them. The nerve connections to the layer are gathered together and pass out of the back of the eyeball via a flexible multi-core cable to the brain.

In the centre of the retina immediately opposite the lens, the layer is thinned away into a small depression called the fovea. Partly due to the fact that the light penetrates more easily at this point, the fovea is highly sensitive. It can be seen through an ophthalmoscope and looks like a small dark dot about the size of a pin's head. It is only at this tiny spot that the eye can perceive a really sharp, clear image.

As soon as anything 'catches one's eye', a reflex action swings the eye round involuntarily so that the image is centred on the fovea; but the fovea is so small that it can see only a small piece of any object at a time. To see the whole object clearly, the eyeball has to perform a series of scanning motions by which the fovea is able to examine each detail in rapid succession.[2] During the process the focus of the lens can be altered from moment to moment, so that the scanning to some extent takes place in three dimensions. As a result of this mechanism the eye seems able to perform a kind of 'electronic zoom', similar to the effect produced by expanding the scan of a television camera. Also, stereoscopic appreciation is much enhanced, especially as it is possible that the scanning action of each eye operates independently of the other.

Research into the act of perception has shown that the visual centres perceive complete patterns rather than discrete dots, and certain sections of the brain look as if they might be 'wired up' to form an electrical scanning system designed to review the totality of information from the retina from moment to moment.[3]

The retina is now thought to contain at least seven different kinds of colour receptors. By means of selecting and cancelling irrelevant information, the nervous mechanism compensates completely for the chromatic aberration of the optical system. Also, since each eye of the pair sees a given object from a different position, the brain not only combines the two sets of information into a single impression, but suppresses all the double images of objects behind the point upon which the eyes are converged.[4]

Now let us apply this information to the case of a man sitting in a theatre watching a play. In the first place, there is no physiological reason why he should look at the play at all, so in order to make sure his eye does not wander away, the auditorium is darkened and the stage becomes the only place where anything can be seen. The spectator's eyes now rest upon the point of interest within the proscenium frame. This point of interest varies from moment to moment as the play progresses, and is shifted about by four devices:

(*a*) Grouping of the actors.

(*b*) The direct engagement of interest by the spoken word, which can not only attract interest towards its point of origin, but also suggest and anticipate other points of interest; e.g. the well-known pantomime gambit: 'Look, here she comes'.

(*c*) Gesture, which can either attract or redistribute attention.

(*d*) Lighting. There is a direct relationship between the apparent brightness of an acting area and the degree of attention. Difficulty in seeing the actor's face will actively distract the audience from the play to the process of vision, while complete blackness will produce involuntary diffusion of attention. The spoken word alone, without a visual fixation point, cannot hold the attention for very long.

All these devices, of course, can and should be used by the producer to direct the spectator's eyes to the significant dramatic action.

As we have seen, the eye is so constituted that the spectator *must* view the scene serially, but he can expand or reduce his 'area of scan' so that he appears to himself to be quite free to view either a single actor or a complete panorama at will.

Also, there appear to him to be no out-of-focus areas anywhere, because as soon as his attention is attracted to any point he moves his eye and re-focuses to that point, while the unfocused areas on the periphery of the retina are mentally suppressed.

In contrast to the theatre audience, a television viewer is examining a small area rather less than a foot square. This area has no depth and is only a few feet away, so that both a relatively high degree of unvarying focal accommodation and a high degree of convergence are required from the eyes. Also, many people are long-sighted and in order to be able to focus the picture have to sit so far away that the screen appears much too small. On the other hand, if the spectator is too close or the screen too wide (as in the front seats of a cinema) the eye has to scan much too large an area for comfort and feels correspondingly overworked.

Now the camera gives the producer a new weapon with which to concentrate attention. Instead of tempting the roving eye to look first on this area and then on that, the camera—like an opera glass—gives an enlarged view of the activities at the point of interest in the scene, at the expense of limiting the viewer's freedom completely. This is perfectly successful, provided the camera is in fact focused upon the spectator's point of interest; but as we have seen, the point of interest moves around with the progress of the drama. The moment the spectator's eye wishes to move and the camera fails to move, or moves too soon, the limitations imposed on the eye become apparent and the spectator feels frustrated. This, of course, equally applies to focus within the frame of a given picture. Out-of-focus areas and double images are always present to the eye, and provided the camera is focused on the point of interest, the out-of-focus areas will not be noticed; in fact, they will add to the illusion of depth. The most natural situation exists when the point of interest is sharply focused and everything else is blurred, yet the spectator has no desire to examine any part of the picture except the sharply focused part.

The human eye has been evolved to respond to happenings of biological significance. A shadow, from the point of view of physics, may be caused by the absence of light. The eye, however, regards the shadow as positive; it might so easily be the shadow of a tiger! Accordingly the retina is fitted not only with nerve endings that respond to light, but other nerve endings that are triggered in reverse phase by darkness;[2] this may explain why black paint on a white ground is just as significant to human vision as white paint on a black ground. Psychologically, we can regard the absence of light in two distinctly different ways. Firstly, as darkness or dimness, which is felt as an empty negative quality; secondly, as black or grey, a well-defined area reflecting relatively little light, which is felt as a positive reality. In a black and white photograph, therefore, we find that black has the same emotional quality as a colour; e.g. a girl's lipstick on the screen is always darker, never lighter, than her face; and the more vivid the colour, the *blacker* should be the reproduction.

This means also that productions such as ballet, which in the theatre rely for their effect on brilliant colours, need to be re-designed for television in terms of black and white patterns, something quite different psychologically from the mere panchromatic rendition of colour in tones of grey. We are accustomed to regard a black-and-white picture as an imperfect reproduction of a naturally coloured scene. On the contrary, when everything is under the control of the producer as in the studio, the black-and-white reproduction and *not* the studio scene is the finished article, as complete and self-sufficient as a Rembrandt etching.

5. CAMERA TUBES

5.1 Introduction

It was previously stated that television lighting has two basic requirements to fulfil, namely, the lighting must create the mood, atmosphere or artistic effect called for by the production; and the lighting intensity must be of such a character and value as to be acceptable to the technical needs of whichever type of camera tube is being used. We have dealt with the fundamental principles underlying the first requirement, and we must now consider those of the second requirement.

At the present time there are four different types of camera tube in use at Alexandra Palace, Lime Grove, and on O.B.s, namely, the Standard Emitron, the Photicon, the CPS Emitron, and the Image Orthicon. These cameras have different sensitivities and spectral response characteristics, so that a lighting lay-out which is satisfactory for one type of tube will not necessarily be in the least suitable for another.

The following table gives an indication of average incident and reflected light values employed under operational conditions:

OPERATIONAL LIGHTING VALUES

	Incident Light, foot-candles	*Reflected Light, foot-lamberts*			*Lens Aperture f*
		Peak White	*Average White flesh-tones*	*Black*	
Standard Emitron	200–300	150–250	40–70	3–5	3·0
Photicon	200–250	150–200	40–60	2·5–3·5	2·0
C.P.S. Emitron	100–130	70– 90	20–30	2·5–3·0	6·3
Image Orthicon	25– 30	20– 25	8–10	1·0–1·25	4·6

With all types of camera tube, effects-lighting for moonlight and scenes of darkness should be substantially achieved by suitable lighting in the studio (see Section 3). It is possible, however, to assist the effect by sitting the picture signal down. It will be remembered that by sitting down, the grey tones of the picture content are reproduced as black, so that a studio scene, although illuminated to the normal intensity, can be made to appear dark by lowering the tone values. It is most desirable, however, that the use of sit control should be made only in conjunction with suitable lighting in the studio, and with this purpose in mind a scene that is intended to represent moonlight should be lit to a slightly higher degree of contrast than normal. The reason for this is, of course, that when the picture is sat down the white portions become grey. Added contrast will then assist the white parts of the picture and avoid the compensatory increase of gain which would otherwise be necessary in order to provide the transmitter with peak modulation. With the CPS Emitron it is desirable to create effects of this nature entirely by suitable lighting in the studio, and thus eliminate the use of sit control for effects purposes.

5.2 Gamma

In the details of camera-tube characteristics given below reference is made to values of *gamma.*

Gamma expresses the degree of linearity between the contrast in a scene and the contrast in the televised or photographic reproduction of that scene. The brightness of two points in the original scene is compared and the logarithm of their ratio taken. A logarithm is then obtained from the ratio of the corresponding points in the television image, or photographic positive, or photographic negative. Gamma is then the ratio of these logarithms. If P_1 and P_2 are the two points in the original scene and I_1 and I_2 are their light intensities then their contrast ratio is I_1/I_2 These same two points as reproduced will have new intensities I'_1 and I'_2 and their contrast ratio will be I'_1/I'_2 The gamma is the quotient of the logarithms of these contrast ratios.

$$\gamma = \frac{\log (I'_1/I'_2)}{\log (I_1/I_2)}$$

The gamma of most commercial receiver cathode-ray tubes is between 2·0 and 2·5, so that in order to produce a picture of the desired gamma, the overall gamma of the transmitting equipment must be in the region of 0·5.

If the overall gamma is too high, the picture on the home receiver will be too contrasty, with loss of detail in the half-tones and excessive highlight brightness, an effect commonly known as 'soot-and-whitewash'. This was particularly noticeable on television receivers in the early days of the CPS Emitron before a gamma correction unit was used. Without correction the scene contrast and the lighting contrast had to be kept embarrassingly low.

5.3 Standard Emitron Camera Tube

The Standard Emitron camera tube is of comparatively low sensitivity and requires a scene brightness of 150 to 250 foot-lamberts from peak white, and 40 to 70 foot-lamberts from flesh tones for satisfactory operation at the full aperture of f/3 with the 6½ in. lens. The mosaic requires an illumination of 4 foot-candles. In terms of incident light upon the scene this represents a figure of 200 to 300 foot-candles. It does not follow, however, that a scene illuminated to this value will necessarily produce good quality pictures, for while it is essential to provide adequate illumination, it is also essential to position the light sources in such a manner that the light distribution does not change too violently when a camera is panned across the scene. Large variations in scene brightness must therefore be avoided. Furthermore, large areas of uniform brightness should also be avoided or broken up, so that the picture composition contains a reasonable a.c. content.

The signal generated by the Emitron does not increase in proportion to the intensity of light falling on the mosaic; in fact, the efficiency of signal generation decreases with increasing light intensity, ultimately saturating at a very high value.

The gamma of the Standard Emitron is approximately 0·6 at low light levels.

This figure decreases slightly as the mosaic illumination is increased. The optimum contrast range of the Standard Emitron can be taken as approximately 50:1. It will handle more than 50:1, but not entirely satisfactorily.

As has already been explained in Section 2.2 it is desirable that objects should be included in the picture with suitable reflectance values in order to take full advantage of the 50:1 contrast range. Normal flesh tones have an average reflectance value of 30 per cent to 40 per cent and some of the best pictures of speakers, announcers, etc. taken in mid-shot result when the setting is arranged to include a black telephone to conform to black level, and some light-coloured flowers or similar decorations to produce peak white. If suitably illuminated the flesh tones will then fall conveniently between the two.

With the Standard Emitron the lighting contrast for a close-up should be in the ratio of 2:1 between the key light and the filler. The back-light intensity will depend on the reflectance value of the person's hair, but for the average brunette it should be between one and one and a half times the intensity of the key light. In the case of fair-coloured hair the back-light intensity must be suitably reduced.

5.4 Photicon Camera Tube

The Photicon camera tube, although intrinsically more sensitive than the Standard Emitron, in practice requires approximately the same lighting levels because such sensitivity is automatically translated into improved depth of focus. It requires a scene brightness of 150 to 200 foot-lamberts from peak white, and 40 to 60 foot-lamberts from flesh tones for satisfactory operation with a lens aperture of f/2·0. In terms of incident light on the scene this represents a figure of 200 to 250 foot-candles. The gamma of the Photicon at the centre of its characteristic curve is 0·5 and falls to between 0·2 and 0·3 at highlight levels. It is undesirable to use high levels of illumination because at the bend-over point of the curve photo-cathode noise becomes apparent.

The optimum contrast range is approximately 60:1 and, like the Emitron, it will handle more but not satisfactorily. Because of the compression which occurs at the top of the characteristic curve, greater lighting contrast is required to produce satisfactory pictures. This should be to the ratio of $2\frac{1}{2}$ to 1 between key light and filler, and the back light-intensity for an average brunette $1\frac{1}{2}$ to 2 times the intensity of the key light.

5.5 C.P.S. Emitron Camera Tube

The C.P.S. Emitron camera tube is considerably more sensitive than the Standard Emitron or the Photicon, and requires an average scene brightness of 70 to 90 foot-lamberts from peak white, and 20 to 30 foot-lamberts from flesh tones. This represents an incident light value of approximately 100 to 130 foot-candles for operation at f/6·3.

The signal generated is proportional to the mosaic illumination, i.e. the tube has a gamma of unity. If no gamma correction were available, the C.P.S. camera would demand scenes of very low contrast, so much so as to be impracticable for studio use, but by controlling gamma it is possible for scenes of reasonable contrast to be employed. With the present type of gamma correction the sensitivity of the

C.P.S. Emitron does not change appreciably throughout the range of correction.

The overall contrast range of the studio setting designed to be used with the C.P.S. Emitron should be approximately 30:1, and should not exceed 40:1. The lighting contrast between key light and filler should not exceed $1\frac{1}{2}$ to 1. Back lighting must be carefully used from as low an angle as possible, and strong overhead lighting should be avoided. For base lighting purposes, large area sources should be used to build up a standing level of illumination of approximately 50 foot-candles incident. It is necessary to build up the overall lighting in this way and then add key light, filler and back light to the correct ratios. The key light should be between 1 and $1\frac{1}{2}$ times the intensity of the base lighting, and the back lighting between 1 and $1\frac{1}{2}$ times the key lighting. The C.P.S. Emitron will produce pleasing pictures, both from the technical and artistic sense, if the character of the lighting is correct. It will not handle violent lighting contrasts satisfactorily, and it is important to remember that lighting effects must be of a subtle nature. Differences in quality or direction of lighting are preferable to changes in brightness.

5.6 Image Orthicon Camera Tube

The Image Orthicon camera tube has, as the result of considerable experience in the U.S.A., been found to require a base light level of 110 to 130 foot-candles when using incandescent lamps in order to produce good quality pictures.[5] It is said that this intensity of base lighting is necessary to provide an even lighting level throughout the scene when the cameras are used with a Wratten No. 3 or No. 6 filter. Key lighting should be added to the extent of 1 to 2 times the base light level and back lighting, directed from the lowest possible angle, should have an intensity of 1 to $1\frac{1}{2}$ times the base light level. Top lighting should be avoided. Modelling light used from the side-front position should be adjusted to give an intensity of between a $\frac{1}{2}$ and 1 times the base light level. To provide sparkle in the artist's eyes a small amount of frontal light may be used, of approximately $\frac{1}{2}$ to 1 times the base light level.

Our experience in this country of the Image Orthicon has very largely been limited to O.B. work, where lighting is always a compromise. Artistic effects are usually unobtainable and illuminators have of necessity to be placed in the best available positions, even though these positions may be far from satisfactory artistically. However, the working levels of light intensity have shown that pleasing results can be obtained with an incident light value of 25 to 30 foot-candles. The average reflected light value from peak white should be approximately 20 to 25 foot-lamberts, and from flesh tones 8 to 10 foot-lamberts. This enables the camera to work satisfactorily at about f/4·6. Satisfactory pictures in the technical sense can be obtained with the Image Orthicon by using base lighting only but, for artistic results, modelling and back lighting are required. More so even than with the C.P.S. Emitron, high contrast ratios and wide variations in lighting conditions must be avoided.

6. LIGHTING APPARATUS

This Section provides details of the lighting apparatus which will normally be available for the illumination of studio productions. Details of lamps are given, including angle of beam-divergence, intensity, weights, etc. as these factors are of the utmost importance when planning production lighting in advance.

The equipment described is that in use at Lime Grove or Alexandra Palace at date of publication. New types of G.E.C. and Kandem lighting units have been produced by the manufacturers and may be used in Television studios in the future.

6.1 Incandescent Filament Lamps

At the present time incandescent filament lamps form the main source of illumination in the Television studios. In addition, compact source high-pressure mercury/cadmium discharge lamps are used in limited numbers and carbon arc lamps are occasionally employed for effects purposes.

Incandescent filament lamps are used either in open reflectors to provide diffused lighting over a wide area of the set or in spotlight form with condenser lens and reflector to produce harder lighting for modelling purposes. The desirable fundamental characteristics of a good lamp of the spotlight type for television use may be summarised as follows:

(1) Reasonable electrical efficiency, i.e. a relatively high ratio of emitted light to power input.
(2) Spectral characteristics matching those of the camera tube.
(3) Accurate control of directivity and beam divergence.
(4) Light beam free from dark centre shadows, hot spots, hot rings, ring shadows or other irregularities whether in the form of lamp mechanism or optical aberrations.
(5) Freedom from spill-light outside the useful light beam. When considering incandescent lamps in open reflectors for the provision of diffused lighting over a large area the characteristics mentioned in (1) and (2) above are necessary and in addition the area of the source should be large enough to provide virtually shadowless illumination when used at a reasonable distance from the studio setting. Incandescent filament lamps consist mainly of standard film-studio equipment; these have been found to be convenient for television use and their advantages and disadvantages can be outlined as follows:

Advantages

(*a*) Continuous spectrum of desirable energy distribution.
(*b*) Silent in operation.
(*c*) Require no auxiliary apparatus.
(*d*) Mechanically and electrically simple.
(*e*) Emit no smoke or fumes.
(*f*) Good reliability.
(*g*) Comparatively light in weight and easy to handle.
(*h*) Require no attention while operating.
(*i*) Maintenance and operational costs reasonably low.
(*j*) No difficulty in obtaining spare parts.
(*k*) AC or DC operation.

Disadvantages

(*a*) Radiant heat.

(*b*) Inefficient producer of light as compared with gaseous discharge lamps or carbon arcs. This relative inefficiency is largely outweighed by the general convenience of incandescent lamps.

In the details of lamps given below all measurements were taken 20 ft from the light source.

M/R Type-414 Lens Spotlight

5 kW Weight 81 lb without stand.

	Spot	*Flood*
Beam divergence	13°	60°
Foot-candles	2,625	200
Spot diameter	4·6 ft	23·1 ft
Diameter of lens	14 in.	Aluminium reflector

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	100	29

This type of illuminator is used with all camera tubes but more especially with the high-velocity types where it is utilised for key lighting, accent lighting or back lighting. It is used to a more limited extent with low-velocity tubes when the length of throw is considerable or when a single shadow effect is required over a reasonably large area. Its flexibility of control and its high luminous output make it a most suitable lamp for use with the less sensitive types of camera tube.

M/R Type-410 Lens Spotlight

2 kW Weight 39 lb without stand.

	Spot	*Flood*
Beam divergence	12°	44°
Foot-candles	1,050	100
Spot diameter	4·2 ft	16·2 ft
Diameter of lens	10 in.	Aluminium reflector

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	200	24·5

This type of illuminator is used extensively with all camera tubes. With the C.P.S. Emitron and the Image Orthicon it is often used for key lighting, accent lighting and back lighting. When employed for back lighting with low-velocity tubes it must be used with discretion, for if the length of throw is insufficient, difficulty may be experienced in obtaining the correct balance between key and back lighting. With the Emitron and Photicon cameras it can be called an all-purpose lamp for set lighting and back lighting for artists in small sets, announcers, etc., for key lighting.

M/R Type-406 Lens Spotlight

500 W Weight 14½ lb without stand.

	Spot	*Flood*
Beam divergence	13°	58°
Foot-candles	205	16
Spot diameter	4·4 ft	22 ft
Diameter of lens	6 in.	Aluminium reflector

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	50	26

This type of illuminator is used extensively with all camera tubes. With the C.P.S. Emitron and the Image Orthicon these small spotlights can be used as key lights for modelling purposes for artists in small sets, announcers, etc.; also for back lighting. With the Standard Emitron and Photicon cameras, their function is usually that of back lighting announcers, erasing troublesome shadows, effects lighting, etc. They are comparatively small in size, so it is often possible to conceal them within the set itself.

M/R Type-404 Lens Spotlight

200 W Weight 3½ lb without stand

	Spot	*Flood*
Beam divergence	10°	54°
Foot-candles	74	4·5
Spot diameter	3·5 ft	20·4 ft
Diameter of lens	4½ in.	Aluminium reflector

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	50	21·5

This type of illuminator can use either a 200-watt or a 100-watt class A1 projector bulb. Its main function is that of back lighting announcers, the elimination of troublesome shadows and special effects lighting for the C.P.S. Emitron or Image Orthicon cameras. It has very little application with the Standard Emitron or Photicon cameras.

G.E.C. Lens Spotlight

5 kW Weight 65 lb without stand.

	Spot	*Flood*
Beam divergence	17°	62°
Foot-candles	2,500	180
Spot diameter	6 ft	24 ft
Lens	16 in. square	Aluminium reflector

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	100	28

The size and shape of this type of illuminator limits its use to floor lighting only—it is never used from the gantry. At the present time it is used only with the Standard Emitron at Alexandra Palace and its main function is that of effects lighting or key lighting when required at no more than stand height above studio floor level.

G.E.C. Lens Spotlight

2 kW Weight 45 lb without stand.

	Spot	*Flood*
Beam divergence	15°	54°
Foot-candles	940	94
Spot diameter	5·5 ft	20 ft
Lens	12 in. square	Aluminium or mirror reflector

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	200	26

The above remarks in connection with the G.E.C. 5 kW lens spotlight also apply to the G.E.C. 2 kW type. Its slightly greater angle of flood as compared with the 2 kW M/R equivalent is advantageous at times when the length of throw is limited.

M/R Type-305 5-Light Fitting

General-purpose illuminator. Weight 69 lb without stand.

Horizontal angle of divergence	96° approx.
Max. breadth of illumination at 20 ft	46 ft
Foot-candles	30 (using 1,000-W bulbs)

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	250	20·8

This type of illuminator is used extensively with all types of camera tubes, for general purpose lighting. It can be used on a stand for floor lighting, or can be suspended when required. It is ideal for the illumination of backings, backcloths, etc. and is valuable for large-area frontal illumination when used with high-velocity camera tubes.

M/R Type-20 Double Broad

General-purpose illuminator. Weight 32 lb without stand.

Horizontal angle of divergence	92° approx.
Max. breadth of illumination at 20 ft	42 ft
Foot-candles	18 (using 1,000-W bulbs)

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	250	20·8

This type of illuminator is used with all types of camera tube for floor lighting purposes, mainly as a soft frontal light or filler.

M/R Type-21 Single Broad

General-purpose illuminator. Weight 18 lb without stand.

Horizontal angle of divergence	78° approx.
Max. breadth of illumination at 20 ft	32 ft
Foot-candles	14 (using 1,000-W bulbs)

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	250	20·8

This type of illuminator is used with all types of camera tube for floor lighting purposes, mainly as a soft frontal light or filler.

Hewitt Large-area Source, 2-4 kW

General-purpose illuminator. Weight approx. 105 lb.

Horizontal angle of divergence	102° approx.
Max. breadth of illumination at 20 ft	50 ft
Foot-candles	15 (using 100-W pearl bulb)

This type of illuminator is used at Lime Grove only, and consists of 24 × 100-W pearl lamps. It is occasionally used with the Photicon cameras, but its main application is with the C.P.S. Emitron where an even distribution of base lighting is necessary. It is not unduly difficult to move about the studio, and suspend from the ceiling runners, in spite of its physical size and shape.

Kandem 8-light Overhead Fitting

General-purpose illuminator. Weight 36 lb.

Horizontal angle of divergence	96° approx.
Max. breadth of illumination at 20 ft	44 ft
Foot-candles	28 (using 500-W bulbs)

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	250	19

This is an out-of-date type of illuminator used only at Alexandra Palace for general illumination. Its use is very limited.

Kandem 15-light Overhead Fitting

General-purpose illuminator. Weight 130 lb.

Horizontal angle of divergence	102° approx.
Max. breadth of illumination at 20 ft	50 ft
Foot-candles	70 (using 500-W bulbs)

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	250	19

This is an out-of-date type of illuminator which has very occasional use at Alexandra Palace only. Its main disadvantage is its size and weight.

Kandem 1-kW Broad

General-purpose illuminator. Weight 20 lb.

Horizontal angle of divergence	79° approx.
Max. breadth of illumination at 20 ft	33 ft
Foot-candles	12 (using 1-kW bulb)

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	250	20·8

This type of illuminator is used at Alexandra Palace only, but its application could quite well be extended to any type of camera tube for general purpose illumination, soft frontal light or filler.

Kandem 2-kW Broad

General-purpose illuminator. Weight 35 lb.

Horizontal angle of divergence	92° approx.
Max. breadth of illumination at 20 ft	42 ft
Foot-candles	17 (using 1-kW bulb)

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	250	20·8

This type of illuminator is used at Alexandra Palace only. It can easily be used with any type of camera tube for general purpose illumination, soft frontal light or filler.

Kandem 2-kW Spotlight

Weight 46 lb.

	Spot	*Flood*
Beam divergence	9°	44°
Foot-candles	2,000	70
Spot diameter	3 ft	16 ft

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	200	24·5

This is an old-fashioned type of illuminator which has very occasional use at Alexandra Palace and Lime Grove. The light beam can be spotted to give a small and intense circle of light, but suffers from irregularities in the form of filament shadows. Although spill-rings are used, they do not prevent a considerable amount of spill-light from areas outside the main light beam.

Kandem 5-kW Spotlight

Weight 65 lb.

	Spot	*Flood*
Beam divergence	10°	60°
Foot-candles	3,000	150
Spot diameter	3·5 ft	23·1 ft

Filament Volts	*Objective Life Hrs*	*Lumens Per Watt*
115	100	29

One illuminator of this type is occasionally used at Alexandra Palace only. It suffers from the same irregularities as mentioned above in connection with its 2-kW counterpart.

6.2 Compact Source Lamps

Three types of compact source high-pressure mercury/cadmium discharge lamps are used:

(*a*) Soft-light sources in specially designed units for general-purpose illumination. (Studios A and B only at present.)

(*b*) Floodlights for backcloths and general-purpose illumination.

(*c*) Spotlights for modelling and effects purposes.

The spectrum produced by a high-pressure mercury discharge lamp is discontinuous, having isolated lines at 5,770/5,790A (yellow); 5,461A (green); 4,047A (blue); and 3,650A (ultra-violet), but by the addition of cadmium a fairly strong red line at 6,438A partly balances the deficiency in red in the mercury vapour spectrum. The cadmium also produces a line at 5,086A which fills the gap between the blue and green mercury lines. Mercury/cadmium compact source lamps are consequently suitable for television use, and their relative advantages and disadvantages may be outlined as follows:

Advantages

(*a*) Cool radiation; radiant heat is about 25 per cent only that of incandescent.

(*b*) Silent in operation.

(*c*) Emits no smoke or fumes.

(*d*) Requires no attention while operating.

(*e*) Mechanically simple.

(*f*) Reasonable voltage surges in an upward direction have little lasting effect.

(*g*) Slightly higher luminous efficiency for a given power input than for incandescent.

(*h*) Output more constant than tungsten, 1 per cent voltage drop producing 3 per cent as against 4 per cent drop in intensity, as compared with incandescent on 115V.

(*i*) Apparent reduction in camera noise, probably due to the smaller amount of infra-red radiation of the compact source lamp as compared with incandescent.

Disadvantages

(*a*) Reliability factor lower than incandescent.
(*b*) Maintenance costs higher than incandescent.
(*c*) High cost of bulb replacement.
(*d*) Requires auxiliary apparatus in the form of ballast resistance, control equipment and pulse starting gear.
(*e*) Considerable heat dissipation in ballast resistances.
(*f*) Electrically relatively complex.

In the details given below all measurements were taken 20 ft from the light source.

M/R 5-kW Spectre

Weight of lamp 190 lb Weight of grid 105 lb.

	Spot	*Flood*
Beam divergence	16°	48°
Foot-candles	4,150	390
Spot diameter	5·6 ft	17·8 ft
Lumens per watt	Approx. 50, depending on cadmium content of bulb	

One M/R 5-kW Spectre is available for use as required either at Alexandra Palace or Lime Grove.

It can be used to great advantage for providing hard, contrasty lighting for simulating sunlight. The beam divergence is normally controlled remotely and the lamp may also be simmered by operating a switch on the remote control unit to conserve both power and lamp life.

G.E.C. 2·5-kW Spotlight

Weight 100 lb.

	Spot	*Flood*
Beam divergence	12°	36°
Foot-candles	2,500	225
Spot diameter	4 ft	13 ft
Lumens per watt	45, depending on cadmium content of bulb.	

One G.E.C. 2·5-kW spotlight is available for use as required either at Alexandra Palace or Lime Grove. It is useful for producing sunlight effects through windows, and other effects requiring illumination of high contrast.

This lamp is housed in a G.E.C. 2-kW incandescent filament lamp unit, with the control equipment mounted underneath the housing. The weight of the control equipment results in the lamp unit being poorly balanced at its yoke pivot point.

G.E.C. 2·5-kW Flood

Weight 106 lb.

Beam divergence	100° approx.
Foot-candles	70

Max. breadth of illumination at 20 ft	48 ft
Lumens per watt	45

Two 2·5-kW G.E.C. floodlights are available for use either at Alexandra Palace or Lime Grove, for general-purpose illumination, lighting backcloths, etc. It is a self-contained unit having its control equipment, ballast resistance, etc. incorporated within the lamp housing. Two side-wings of the reflector are arranged to hinge so that they can close round the lamp. Closing the reflectors introduces extra resistance into the lamp circuit and reduces the wattage to about 1,000. Interlocks are provided to prevent the lamp being switched on with the shutters open, and to prevent the mains polarity being applied in reverse.

G.E.C. 2·5-kW Soft-light Fitting

Weight approx. 80 lb.

Beam divergence	130° approx.
Foot-candles	18
Max. breadth of illumination at 20 ft	86 ft
Lumens per watt	45

Six of these units are at present in use at Alexandra Palace, three per studio, for the provision of diffused lighting over large areas of the studios. Their control equipment and ballast resistances are mounted on the studio walls at gantry level. The physical size and shape of the lighting units prevent them from being moved about the studio.

It is interesting to note that of the compact source lamps mentioned above, the M/R 5-kW Spectre is the only one which has hot-starting facilities; thus, if a temporary mains failure should occur lasting no more than a few seconds, the G.E.C. lamps would require ten to fifteen minutes for cooling purposes before being re-started.

At Lime Grove studios the soft light for base-lighting purposes is derived from Hewitt banks consisting of 24 100-W pearl lamps mounted in a rectangular framework. In many ways these are similar in construction to the banks used at Alexandra Palace, but at Alexandra Palace the framework contains 48 100-W pearl lamps. The figures given below indicate the comparison between one 2·5-kW compact source soft light and a 48-light incandescent bank. The illumination is measured in foot-candles and the figures in brackets are for the incandescent bank. Measurements were made at 4-feet intervals on a rectangular grid, and the value given at the top right-hand corner of the table was found vertically below the centre of the lower edge of the fitting. The table thus gives the illumination over one-half of the lighted area.

28	55	82	90
(22)	(41)	(55)	(55)
42	79	107	115
(22)	(36)	(55)	(55)
42	66	94	97
(30)	(37)	(51)	(55)
35	55	62	70
(25)	(35)	(41)	(47)
28	35	45	49

6.3 Carbon Arc Lamps

In the past, carbon arc lamps have had little application in the Television studios apart from occasional use for effects purposes. At the present time, however, they are being employed to some advantage with the Photicon cameras at Lime Grove. They are also used on some OBs, where the length of throw is considerable. Their spectral characteristics are a combination of the continuous spectrum produced by the carbon, upon which is superimposed the line and band spectra from the vapours of the arc. The spectrum produced lies approximately mid-way between that of mean noon sunlight and that of an incandescent lamp operated at a colour temperature of approximately 2,800 to 2,900° K.

Their advantages and disadvantages can be summarised as follows:

Advantages

(*a*) Higher luminous efficiency than incandescent or compact source lamps.
(*b*) Cool radiation.
(*c*) Good reliability.
(*d*) Electrically simple.
(*e*) Desirable where high level of illumination is required.
(In the studios this is generally necessary for effects purposes.)

Disadvantages

(*a*) Requires auxiliary apparatus in the form of ballast resistance.
(*b*) Maintenance costs higher than incandescent, but lower than compact source lamps.
(*c*) Mechanically relatively complex.
(*d*) Requires attention while operating.
(*e*) Emits smoke and fumes.
(*f*) Carbons require changing after relatively short period of operation, i.e. maximum 1½ hrs.
(*g*) Considerable heat dissipation in ballast resistance.
(*h*) Operation on d.c. only. (Generally speaking.)
(*i*) May be troublesome with noise, especially in small studios.
(*j*) Can only be satisfactorily operated in large well-ventilated studios.
(*k*) Cost of carbon replacements high in comparison with incandescent bulb replacements.
(*l*) Considerable labour force required for replacement of carbons and general maintenance if many of the lamps are used.

At present one M/R Type 65 carbon arc is available for use either at Alexandra Palace or Lime Grove, as required. In addition two 150-amp arcs are retained for service at Lime Grove. From time to time other arc lamps are hired. Details are given below:

M/R Type 65

65-amp high-intensity arc lamp. Weight 77 lb for head only; 46½ lb for ballast resistance.

	Spot	*Flood*
Beam divergence	10°	46°
Foot-candles	1,650	170
Spot diameter	3·5 ft	17 ft

M/R Type 90

120-amp high-intensity arc lamp. Weight 123 lb for head only; 65 lb for ballast resistance.

	Spot	*Flood*
Beam divergence	10°	44°
Foot-candles	5,000	375
Spot diameter	3·5 ft	16·1 ft

M/R Type 170

150-amp high-intensity arc lamp. Weight 162 lb for head only; 69 lb for ballast resistance.

	Spot	*Flood*
Beam divergence	14°	48°
Foot-candles	10,000	1,150
Spot diameter	4·9 ft	17·8 ft

M/R Junior Effects Spotlight

This can be used at 120, 150 or 225 amps. The following table will give an indication of its performance when running at 150 amps at 115 V. (When running at 120 amps the readings should be reduced by approximately 25 per cent, and when running at 225 amps they should be increased by approximately 75 per cent.)

Spot Diameter	*Average Foot-candles*	*Average Foot-candles at 25 ft*
11 ft 6 in.	360	1,500
9 ft	500	2,150
6 ft	710	3,250
3 ft	980	4,500
1 ft	1,100	5,200

Throw	*Maximum Spot Size*	*Minimum Spot Size*
50 ft	diameter 11·5 ft	diameter 1 ft
100 ft	,, 22·5 ft	,, 1·5 ft
150 ft	,, 33·5 ft	,, 2 ft
200 ft	,, 44·5 ft	,, 2·5 ft

The distribution of light over the spot diameter is such that the brightness is approximately 10 per cent greater at the edge than in the centre, in order to give an apparently even distribution.

6.4 Fluorescent Lighting

Experiments were carried out with fluorescent tubes in connection with the Standard Emitron in 1946–7, and it was at that time found that fluorescent lighting was not satisfactory for Television use. The reasons for this are outlined under 'Disadvantages' (see below), but with the advent of the Image Orthicon it has been decided that further experiments should be carried out. The advantages and disadvantages of fluorescent lighting may be outlined as follows:

Advantages

(*a*) Cool radiation.
(*b*) Luminous efficiency higher than incandescent.
(*c*) The comparatively large area of the light source ensures uniform distribution of illumination.

Disadvantages

(*a*) Comparatively low-wattage tubes only available.
(*b*) With the Standard Emitron their operation on a.c. created stroboscopic flicker, even when balanced across three-phases.
(*c*) Their operation on 110-V d.c. is not entirely satisfactory because of cataphoresis, and it is necessary to change periodically the polarity of the applied potential.
(*d*) Fluorescent tubes of the larger wattages, i.e. 80 to 125 watts, are normally 5 to 8 ft in length and consequently somewhat fragile and difficult to move around the studio.
(*e*) Cost of lamp replacement higher than incandescent.
(*f*) Requires auxiliary apparatus.

It is preferable to operate fluorescent lamps on a.c. rather than d.c. to prevent cataphoresis, i.e. end darkening—an effect caused by mercury ions moving towards the discharge cathode. In lamps of normal design it is necessary to change the polarity after a maximum period of five hours' operation. Cataphoresis is not a gradual phenomenon, but occurs rapidly after a certain period of operation. Once the polarity is reversed, however, the darkening quickly disappears.

6.5 Trends in Development

Until recently the comparative insensitivity of the Standard Emitron combined with the restricted space in the studios at Alexandra Palace have tended to restrict the development of television lighting technique. Experience with the newer types of camera has shown already that lighting has almost unforeseen possibilities for the future. At the moment, while greater sensitivity has reduced the intensities involved, the greater elaboration or size of shows has made the task of the lighting staff even more complex. The position of the illuminators must be more exact: the balance between key light, back light and filler, when using low velocity tubes, is so delicate that special means for micrometer control of brightness may have to be sought. The increased elaboration of scenery portends development of new and more speedy methods of rigging lighting equipment. Improved facilities for control of lighting effects during the progress of a production may also solve some of the artistic problems which are at the present time so intractable; while advances in sound technique, such as the introduction of highly directional microphones or the possible use of recorded speech for certain scenes, might radically simplify the boom-shadow difficulties outlined in Section 2.4.

APPENDIX

ANALYSIS OF AN ACTUAL LIGHTING SET-UP IN A FULL-SCALE PRODUCTION

Fig. 7 is a floor plan of Studio D Lime Grove, showing the layout of the scenes for a play entitled *Dial M for Murder*, produced by Ian Atkins. This production was selected at random and represents a typical routine assignment for the lighting staff. Three C.P.S. Orthicon type cameras and two microphone booms were used on the production, moving from set to set as the action of the play progressed. Six additional fixed microphones were also used. There are several sets, involving the use of 66 lamps with a total connected load of 92·8 kW. The time taken to place the lamps in position and set them was approximately nine hours.

To analyse the whole of the lighting would only confuse the reader and fortunately it is not really necessary as each set is a separate unit with its own lighting. The example chosen can be considered a typical treatment.

Fig. 8 shows a plan of the interior main room set with the lighting units marked in. All the lamps except No. 6 are suspended above the scenery. On the actual production there were ten basic camera tracking-lines for this set, using three cameras simultaneously, together with two microphone booms in the position shown. As one boom was allocated to each half of the set, the lighting is divided into two separate acting-areas which are individually lit, except for general frontal lighting. To simplify the description still further the left-hand half of the set only will be considered, comprising the area shown in the photographs given in Figs 9, 10, and 11.

As C.P.S. Orthicon cameras were used, the technical requirements were that the contrast ratio be restricted to about 30:1 and the overall level of illumination must appear substantially the same to the camera as it pans round the set. On the other hand these cameras have great sensitivity and the overall level required can be achieved quite simply (see Section 5.5). The main frontal lighting was therefore supplied by four soft-light banks of 2,400 watts each. (Nos. 1–4 in Fig. 8.) The result when these alone illuminate the set is illustrated in Fig. 9. Note the lack of modelling, uniform tone, absence of definite shadows, lack of contrast between girl and furniture.

Leaving the soft-lighting on, we now add six lens spots with the result shown in Fig. 10. All the lamps are suspended above the scene, except No. 6.

Taking them in order:

Lamp No. 5. A 5-kW lens spot producing the effect of sunlight through the window and casting the girl's shadow on the floor.

Lamp No. 6. A 2-kW floor lamp supplementing No. 5. It is producing the splash of sunlight in the desk knee-hole.

Lamp No. 7. A $\frac{1}{2}$-kW lamp giving a small amount of additional modelling in the desk area.

Lamps Nos. 8 and 9. Two $\frac{1}{2}$-kW spots which bring out the mouldings on the staircase panelling.

Lamp No. 10. A 3-kW flood, lighting the staircase and the wall behind it.

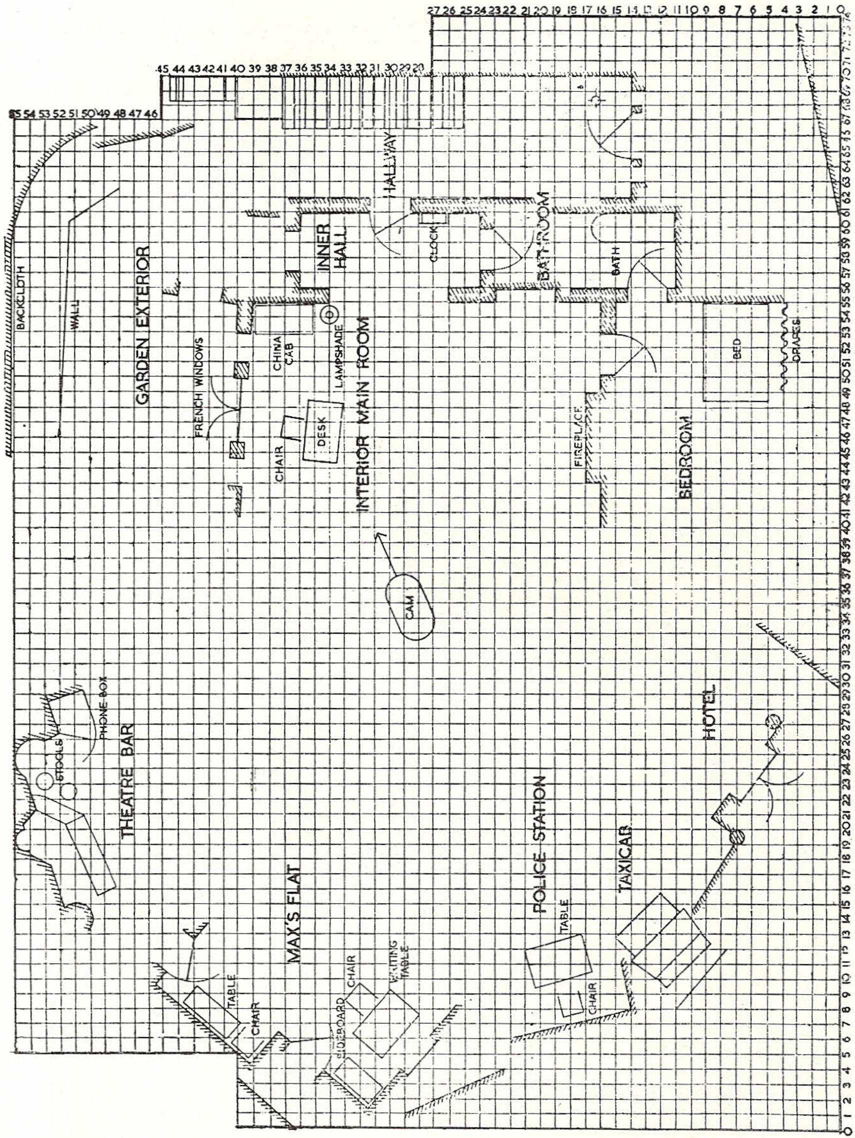


Fig. 7. Studio D, Lime Grove. Floor Plan for 'Dial M for Murder'

Note the increased impression of depth produced by the bright tone of this wall as compared to its appearance in Fig. 9. (See discussion on lighting perspective, Section 3.)

Photograph 11 shows an alternative effect for night. To obtain increased contrast and reduce the brightness of the walls, all the soft-light banks except the centre one (No. 3) have been taken out. The sunlight (Nos. 5 and 6) is out also. No. 7 remains. It is seen to be casting a faint shadow of the lampshade on the door upstage. As the door is now closed, Lamps 8, 9, and 10 are ineffective.

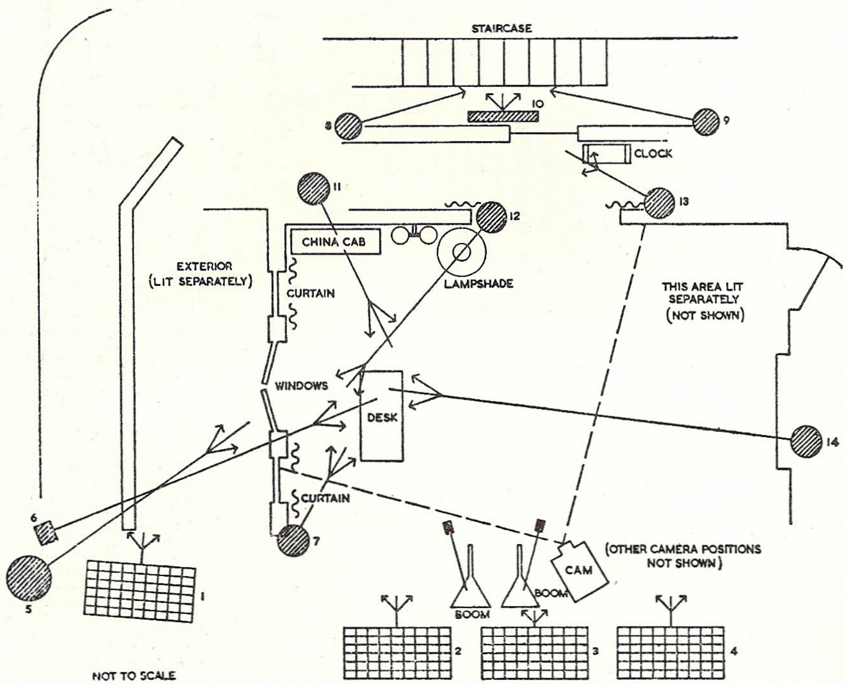


Fig. 8. Interior Main Room Set. 'Dial M for Murder'

The following lamps have been added:

Lamp No. 11. 2-kW back light. This is lighting the girl's hair and casting her shadow on the floor. Compare the position of this shadow with the 'sunlight' shadow in Fig. 10.

Lamp No. 12. $\frac{1}{2}$-kW spot lighting the desk and the window-curtains. (Its presence is indicated by the shadow of the chair behind the desk.)

Lamp No. 13. $\frac{1}{2}$-kW spot directed towards the door and the grandfather clock.

Lamp No. 14. 2-kW spot acting as key light for the desk area. Note the increase in brightness of the front of the desk.

Fig. 9. Scene from 'Dial M for Murder'. Basic Frontal Lighting

Fig. 10. Scene from 'Dial M for Murder'. Lighting for Sunny Day Effect

Fig. 11. Scene from 'Dial M for Murder'. Lighting for Night-time Effect

This alteration in atmosphere has been achieved by the following changes in tone, comparing Fig. 11 with Fig. 10.

(1) It is black through the window panes.
(2) The desk knee-hole is now black.
(3) The light seems to be coming from the general direction of the standard lamp.
(4) The wall is much darker.
(5) The door and the clock are much brighter.
(6) The lampshades have changed their tonal gradation because they are now lit from inside. Nevertheless, the lampshade in Fig. 11 is, if anything, rather darker than in Fig. 10.

A clue to the low light levels being used is given by the pattern of light which the standard-lamp is casting on the wall above it. This is a natural effect in a real room and is being produced naturally here. With high-velocity type camera tubes, the overall level of lighting would be so much greater that this pattern would be practically swamped. If required it could be faked in again using a spotlight masked to give the required shape. The same remarks apply to the brightly illuminated area of wall underneath the lampshade.

It should be observed that although in essence this lighting plot seems to be extremely simple, we are really analysing the results of two days' work in the studio. These lamps have undergone a continuous process of minor adjustment in brightness and positions as rehearsals proceeded and the plot as it stands satisfies the requirements of cameras, booms, actors' positions and atmosphere in the manner required by the particular style of this production.

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