POST-WAR BUILDING STUDIES

NO. 12

THE LIGHTING OF BUILDINGS

BY

THE LIGHTING COMMITTEE
OF THE BUILDING RESEARCH BOARD
OF THE DEPARTMENT OF
SCIENTIFIC & INDUSTRIAL RESEARCH

LONDON: 1944
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POST-WAR BUILDING STUDIES

The series of Reports being published under the title of Post-War Building Studies owes its origin to a desire expressed by professional and other institutions connected with the building and civil engineering industries to assist and support the Ministry of Works in regard to post-war plans. During the latter part of 1941 the then Minister, in order to take advantage of these offers of assistance, which he was receiving from all quarters, encouraged the establishment of a series of Committees to investigate and report on the major problems which were likely to affect peace-time building. He also offered, on behalf of the Ministry, to provide the necessary staff and organisation to co-ordinate the various inquiries, in such a way as to avoid duplication of effort and to secure so far as possible uniform direction and policy.

A list of the Reports in this Series is given on the back page of the cover.

The Committees were either appointed by a Government Department or convened by a professional institution, a research association or a trade federation, as seemed most appropriate in each case; and they were so constituted as to ensure that the Reports contain the considered views of experts and others closely concerned with the subject. The Minister gratefully acknowledges the work of the Committees and the valuable assistance given both by the various convening bodies and by the individual members. The Reports are not official publications in the sense that the Government as such is responsible for or necessarily accepts the views expressed, but their contents are authoritative and must be of great value to all now concerned with preparations for building.

LONDON: 1944

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

COMMITTEE ON THE LIGHTING OF BUILDINGS

To the Building Research Board:

GENTLEMEN, We, the Lighting of Buildings Committee, beg leave to present a Report on the inquiries which we were appointed by you, in February 1942, to undertake with the following terms of reference:

i. To review existing scientific information and practice in this country and abroad on the lighting of buildings.

ii. To make recommendations for practice in post-war buildings.

iii. To make such recommendations for further research as may suggest themselves in considering (i) and (ii).

We have held twenty-four meetings. In addition there have been separate meetings by two sub-committees which were appointed, one to study Natural Lighting and the other to study Artificial Lighting, who have been responsible for the preparation of much of the material in this Report.

We have made a study of the general principles of lighting and have considered in detail the lighting of dwellings and schools. In view of a request from the Ministry of Works to present a Report at an early date, it has not been possible to complete a detailed study of other types of buildings at this stage.

SOURCES OF INFORMATION

In fulfilment of our terms of reference we have reviewed existing published information and in addition have taken evidence from a number of experts and bodies having special experience in different directions.

Our attention has been drawn to the fact that there may be special conditions which apply to practice in Scotland and this has been kept in mind during our work.

We have invited a number of bodies to present evidence and the following is a list of those which have done so:

British Electrical Development Association Electrical Contractors' Association Inc. Electric Lamp Manufacturers' Association Electric Light Fittings Association The Illuminating Engineering Society	The lighting of dwellings, schools, and offices.
The Institution of Gas Engineers The Society of Women Housing Managers	The lighting of dwellings.

In addition the following individuals were invited to present evidence:

P. V. Burnett, Esq., F.R.I.B.A., who, while a member of the Committee, was invited to give evidence in his personal capacity.

H. E. Dance, Esq. F. Jackman, Esq., A.R.I.B.A. A. R. Maxwell-Hyslop, Esq.	School lighting.

In order to obtain additional information regarding existing practice in the lighting (natural and artificial) of dwellings, an arrangement was made for Mr. Dennis Chapman and Mr. Geoffrey Thomas of the Wartime Social Survey to carry out an inquiry. A further survey dealing largely with natural lighting in flats was carried out jointly by the Wartime Social Survey and the Building Research Station.

It was felt necessary to confirm by trials the recommendations we proposed to make on the artificial lighting of dwellings. For this purpose a number of ordinary domestic rooms were used and installations were arranged for gas and electric lighting. In one case two flats were placed at our disposal by the London County Council. The trial installations were arranged for us by members of the Gas and Electrical Industries. Additional information on the lighting of communal stairs and passages was given to us by E. J. Stewart, Esq., M.A., B.Sc., F.I.E.S., and much assistance was also given to us by J. B. Carne, Esq., B.Sc., and A. J. Burbidge, Esq.

We wish to record our appreciation and thanks to the individuals, associations, and authorities mentioned in the preceding paragraphs. Their help, very willingly rendered, has been invaluable.

We also wish to express our grateful thanks to the members of the staff of the Department of Scientific and Industrial Research to whose efficient work and co-operation the effectiveness of our work has largely been due. The major secretarial burden has fallen upon Mr. C. C. Handisyde and Mr. W. Allen of the Building Research Station. Mr. T. Smith and Dr. J. W. T. Walsh of the National Physical Laboratory have given most willing and valuable assistance throughout the work, as also has Mr. W. R. Stevens.

We also wish to thank the General Electric Company Ltd. for permission to include Plates 2, 3, 4, and 5.

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THE LIGHTING OF BUILDINGS

A REPORT BY THE LIGHTING COMMITTEE OF THE BUILDING RESEARCH BOARD OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

GENERAL SCOPE OF THIS REPORT

1. THE Report opens with a brief discussion of the principles of lighting and vision and of their influence on design by discriminating between those factors in lighting which, on the one hand, can be measured and prescribed with relative precision, such as quantity of light, brightness, etc., and on the other hand those factors which can only be expressed qualitatively, such as light distribution or contrasts. The qualitative factors are as important for good lighting as those which can be readily measured and specified, but they sometimes tend to be forgotten because it is not possible to specify exact requirements. These factors which are concerned with quality of light (as opposed to quantity) are discussed in Part I (paragraphs 2 to 18).

Part II of the Report explains the methods of measurement which have been evolved and are recommended for appraising lighting—both natural and artificial. It discusses at the same time principles of design for daylight (including sunlight) and artificial light (paragraphs 19 to 105). Whilst the methods and principles used for artificial light are well known and in constant use, those for natural light are far less established, although well founded. The Report, therefore, deals with design methods for natural lighting in considerable detail, and also discusses the important question of the way in which the development of a site for buildings influences the effectiveness of natural lighting in the rooms.

These considerations are closely connected with those of building height and population density, and have a bearing on the problems of town planning.

Detailed and precise standards of natural and artificial lighting for dwellings are put forward in Part III (paragraphs 106 to 212) in a form which could be translated into Codes of Practice.

Part IV (paragraphs 213 to 269) deals similarly with the lighting of schools to which, of course, the whole of Parts I and II also apply.

The Report ends with short sections upon lighting education (Part V), and future work (Part VI), followed by thirty paragraphs embodying our summary and conclusions.

PART I. LIGHTING AND VISION

GENERAL

2. Appreciation of environment is very largely determined by the skill with which a designer exploits the possibilities of light and the behaviour of the eye. Light is of primary significance in architecture and an element in the refinement of all its parts. It is instructive to note how designers, in the past, working within the framework of accepted forms, refined these stage by stage by careful observation. Windows were studied until they combined the right lighting with charm of appearance. The daylight illumination of great rooms and halls was often beautifully developed to excite some special quality such as spaciousness or dramatic character.

3. To-day the state of refinement is less advanced. Changes in architectural form are occurring, not always for the better, and many of the arrangements for natural lighting are, so far, rough and experimental. The full potentialities of artificial lighting have not yet been realized, and though some of the best installations now seem very good, they may appear crude by to-morrow's standards. In a great many homes and work-places, both quantity and quality of lighting are of a very low standard. Such conditions militate against the health, comfort, and efficiency of the people, and it has been our first aim, therefore, to suggest measures to prevent their continuance. But designers should attempt much further refinement of design than is represented by a mere set of minimum standards. We have set out, therefore, the fundamental principles of lighting and vision, and illustrated their operation with examples.

PRINCIPLES OF LIGHTING AND VISION

4. The most important of the principles of lighting and vision which concern design relate broadly to the amount of light and its quality, particularly in relation to glare and contrast—including light and shade—and also colour.

CONTRAST

5. Good contrasts of colour or brightness (including light and shade) are desirable for satisfactory visibility, because our eyes tend naturally to focus on a good contrast. They can, however, be too strong, and the result is then tiring and confusing.

Contrasts as affected by the direction of light on the central object of attention deserve a special note. Light coming only from one direction develops shadows which contrast strongly and sharply with illuminated parts. This is sometimes found unpleasant in itself, and may be deceptive in industrial work. On the other hand, light coming more or less equally from a number of directions often gives too little contrast and destroys clarity of shape. It is usually best to have a predominance of light from one direction, with a proportion from another or from general diffusion.

GLARE

6. The object requiring our attention should, as far as possible, be the brightest thing in view, for our eyes then turn naturally to it and adjust themselves to that brightness. If something else is brighter, then a conscious effort is required to concentrate on the object of attention, and our ability to see it will be reduced because our eyes will be adjusted for the brighter area. In its more intense forms this effect is called glare, and the extent of the distraction and disability it causes depends on the size of the glare source, its relative brightness, and its proximity to the normal lines of vision. The glare source may be the whole background around the object of attention or merely a localized view of the sky or an exposed lamp. Dangerous consequences, such as accidents in factories, can be caused by serious cases of glare. Less aggravated cases cause annoyance and discomfort. In very mild forms, such as the sparkle of moving water or the glitter of a glass chandelier, however, it may give a pleasant reaction, and effects like these might be employed to good purpose by a designer.

COLOUR

7. Coloured objects and materials owe their appearance to differences in their powers of reflecting light from different parts of the spectrum. Saturated colours—*i.e.* those which are very strong—such as bright reds, yellows, blues, and greens reflect less than their corresponding unsaturated colours, which are diluted with white. The appearance and brightness of any coloured object will also be affected by the proportion of that colour emitted by the source of light. For example,

blues and greens appear brighter in daylight than under ordinary incandescent light, because daylight contains a higher proportion of their colours.

AMOUNT OF LIGHT

8. Acuity of vision improves with increasing illumination, and if the other conditions for seeing are good, this improvement can be continued up to very high levels of illumination. Our eyes do not respond equally to equal changes in illumination, but rather to equal proportional changes. If it is necessary to add one foot-candle to an existing foot-candle for a certain improvement, then to ten foot-candles it will be necessary to add not one, but another ten to secure the same apparent improvement.

This is reflected in the sizes of lamps sold, *e.g.* 25, 40, 60, 100 watts and so on, rather than, say, 25, 30, 35, and 40. It also affects the way illumination is represented graphically in this Report. If an arithmetical scale is used, as on the left diagram in Fig. 1, then a curve varying between 1 and 2 units will not bear any resemblance to a curve varying between 10 and 20 units, though the differences

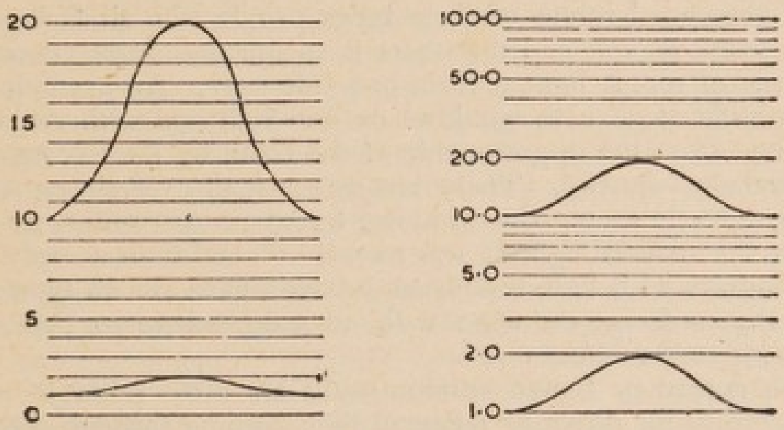


Fig. 1.

will appear equal to the eye. A logarithmic scale will correct this, because equal proportional changes are then represented by equal distances: *i.e.* the space between 1 and 2 is the same as between 2 and 4 or between 10 and 20. Thus the curves on the right-hand diagram will more accurately represent comparative conditions as they will appear to the eye.

This affects also the distribution of illumination. If one is free to move to the best light, there is no difficulty; but if, as in schools and factories, the working positions are fixed, then each should satisfy the principle that it should be, for the person concerned, as bright or brighter than anything else in view. The distribution of light should be sufficiently uniform, therefore, that no one will be conscious of significantly brighter areas around him. A significant variation will usually be one of more than 50–100 per cent.

THE INFLUENCE OF PRINCIPLES OF LIGHTING AND VISION IN DESIGN

9. The bare statement of these principles will not provide the designers with any adequate idea of the numerous and subtle ways in which their operation influences design. We have, therefore, taken some examples from building practice and discussed them to show how vision and illumination play a part in their development.

10. The pleasant lighting in Georgian and some mediaeval buildings is frequently a matter of comment. These are not always generously lighted, and might even appear uncomfortably dark were it not for the excellent seeing conditions usually provided. An important factor in these is the design of the windows, often tall and rather narrow with deep reveals (Plate 1). The height results in good distribution of light, while the deep reveals, in conjunction with the limited width, cut off glare from the eye. Freedom from glare or from the strong contrast of sky seen through a window in a dark wall enables the eyes to adjust themselves to higher levels of efficiency, so that these moderate illuminations may not only appear adequate, but in fact very comfortable.

Deep reveals also provide a gradation of tone from the interior darkness to the light outside, so that contrast is further reduced. Probably the best windows in this respect are the mediaeval types, because they are splayed both inside and out, and therefore give a gradation of tone rather like that on a cylinder. The gradation is often furthered by suitable mouldings. Georgian windows do not usually have the outer splay, but the tone of this part of the reveal is enhanced by rendering it, or painting it white.

11. Even in very good rooms of these types people who sit facing a dark wall perforated by windows will find that there is an uncomfortable contrast. This is particularly true of rooms lighted from one side only. An example of this was seen in a Georgian room with windows on one wall and with the window wall itself illuminated from the opposite side of the room by fluorescent tubes giving light of a "daylight" quality. There was no sense of over-strong contrasts, and anyone sitting directly facing the windows found no discomfort or difficulty in seeing. When the artificial lighting was turned off conditions sharply altered; the contrast of windows with dark wall areas between gave rise to typical sensations of glare, and anyone facing the window found it difficult to see details of persons a few feet away across a table.

Contrasts in curved or bowed window walls are often relieved because there is some opportunity for direct or reflected light coming through the windows to find its way on to the wall surfaces between them.

12. In modern rooms with light decorations lower contrasts between inside and out would generally be expected. They still appear to be too strong, however, partly because in modern thin walls there is so little reveal that there is not much chance to grade tone values. This excessive contrast led to experiments with louvres for daylighting (apart from sunshine control) which are sometimes placed vertically, sometimes horizontally, and often both ways, like a grid across the window. In some respects they no doubt serve the purposes formerly served by the deep reveals, but the results are not always pleasing, particularly when they break the view.

Another modern solution of the problem is found in the practice of running the glazing to the ends of rooms to meet the internal return walls; this avoids having the window framed in a relatively dark surround, for the return wall then takes the place of the reveal, and across it the light falls in evenly graded tones. It seems to be an advantage to have some part of the reveal outside as well as inside, perhaps so that the gradient of tone values is as gradual as possible.

13. Contrast also plays a part in determining how well one sees through a window. In some respects this is best illustrated by considering the case of an observer outside looking into a building. A window with window bars shows up as a grid across a dark void. If the grid is light and close, the chances are that the contrast will be strong enough to induce the eye to focus on it involuntarily, and difficulty will be experienced in seeing into the rooms. The architect's treatment of fenestration in this respect should, therefore, be qualified by the effect he wants to produce on the onlooker. Sometimes he will wish people to be able to see

into the building, and to develop a sense of "transparency" in glazed screens: contrasts would then have to be kept low, by dark window bars or by adequate lighting in the interior. If he merely wishes the window to count as points of dark emphasis, he would again use dark window bars. On the other hand, if it is to be his deliberate aim to reduce visibility into rooms, or to give emphasis to the details of fenestration, high contrast will be desirable.

14. Light walls and decorations are commonly stated to make a room appear larger, and it is interesting to recall that fifty years ago the opposite was thought to be true. A Victorian writer in a book written on the Art of Housekeeping,[1] says that ". . . a dark wall . . . enlarges the apparent size of the room. . . ." Such contrasting advice suggests that perhaps the true functions of either course are not fully appreciated. If apparent size is in fact the aim, one might expect the Victorian adviser to be near the mark, because dark tones are certainly less obvious than light ones and therefore must contribute to a sense of recession.

Dufton describes a case in point [*The Builder*, Vol. 162, 13th February 1942 (Letter to the Editor)]. A fairly large room with a low ceiling was decorated in light cream, yet seemed oppressive. It was redecorated, using a matt black ceiling together with an optical illusion to give the impression of a low vault, and it is reported that the sense of oppression was removed. There is no reason to doubt that the appearance of recession one would expect from any surface of such low brightness contributed materially to the success of this experiment, and in fact it seems reasonable to suppose that light surfaces, rather than apparently enlarging a room, would make its shape more obvious, especially by bringing out the subtle changes in tone values which indicate the change from one plane to another.

One well-recognized advantage of light decorations is the value of reflection, which, with artificial lighting systems in particular, makes an important difference to the illumination of a room. Another, less obvious, point concerns the relation between the brightness of the light sources and of the decoration, and brings in once again this matter of contrast. The modern artificial source of light is usually strong by comparison with older types of equipment, and when put into a dull or darkly decorated room the contrast may make it seem much too bright. In this respect light decorations can be used to lift the whole tone value of a room to a level more in keeping with the brightness of a strong source, and will serve also to reduce contrasts with windows. On the other hand, if a room with dark decoration such as panelling has to be lighted, some caution has to be exercised to secure adequate illumination while avoiding harsh contrasts in light.

15. Proper decoration has also a specific contribution to make to working efficiency. Machinery, for example, is now sometimes coloured to provide restful background effects, and to clarify the motion of many parts. Warning guards and levers are painted in saturated hues of red, bright orange or yellow to draw attention to them; walls, and even floors, are treated in medium or light tones of colours suitably adjusted to give relief and relaxation to the eyes, and to provide suitable contrasts with the decoration of machines and surrounding features.

16. Colour for the general decoration of rooms is commonly the subject of contradictory statements. Some have advocated warm colours in northerly rooms and cool colours in those which face south to compensate for the exposure. Other designers point to the fact that the light is then badly suited to bring out the qualities of colour in the decoration, north light having somewhat more blue in it than south light. We would hesitate to be dogmatic, and there is a suggestion of conflict between the psychological and the physical. Interested designers could usefully experiment on this matter.

[1] Haweis, H. R., *The Art of Housekeeping*, pub. 1889.

17. In artificial lighting systems totally indirect systems were thought at one time to have great advantages for illumination. Reference was made to the excellent distribution of light and its shadowless quality. In time, however, it was found that people did not always like unrelieved indirect light; it seemed "uninteresting" for shapes were poorly defined; and sometimes it was termed "soporific." It was often expensive. Usually it cuts across a basic principle of illumination, for the ceiling rather than the object of attention is likely to be the brightest thing in view.

Wholly direct lighting, too, may have disadvantages. The poor illumination of the ceiling can create a "gloomy" impression to occupants, and give rise also to unpleasant contrasts between the ceiling surface and the lights themselves. Many examples of this can be found in industrial buildings, public halls, and so on, and it is likely to be the case with lay lights. Direct lighting from too few sources gives rise to harsh shadows.

A combination of direct and indirect lighting should generally be the aim; *i.e.* there should be a component of direct light to give interest and clarity of shape to objects and people in the room, and some indirect light to ensure that over-strong contrasts are avoided and that the full effect of the decoration is obtained. This is sometimes done very well in restaurants, where each table has a table lamp and the room has some general light as well. Similar conditions are found in libraries; the British Standard study lamp (Plate 5) can be recommended as a good example of a light fitting based upon these principles.

18. Such examples as we have quoted might be continued almost indefinitely, but our purpose will have been served if we have succeeded in establishing some balance between this part of the Report, which deals mainly with quality, and the sections which follow where the quantitative factors necessarily acquire some prominence. What we hope mainly from the discussion so far, is that in all fields of building practice designers will have an increased appreciation of the relationship between the physiological behaviour of the eye and the nature of their designs.

PART II. METHODS OF MEASUREMENT AND PRINCIPLES OF DESIGN

METHODS OF MEASUREMENT AND PRINCIPLES OF DESIGN FOR DAYLIGHT

THE SKY AS A SOURCE OF LIGHT

19. For the purpose of daylight design, the sky is usually assumed to be a hemisphere equally bright in all parts. In practice this is never exactly true, but it is nearest to being true on those days when it matters most, namely, when the sky is overcast and the general illumination is low. Even under these conditions in this country the south sky is probably twice as bright as the north [1] and the zenith lighter than the horizon, but the assumption provides a satisfactory and workable basis for design.

THE MEASUREMENT OF DAYLIGHT

20. The daylight at a point indoors is usually measured, as in fact it is appraised by the observer, as a percentage of the total light available outdoors under the unobstructed sky, the unit being the *daylight factor*, abbreviated d.f. Absolute units such as foot-candles are impractical for daylight design because of the constant variation of the actual intensities of daylight. A daylight factor of 1 per cent

[1] Illumination Research Technical Paper No. 17, *Seasonal Variations of Daylight Illumination* (H.M. Stationery Office).

signifies that at the point of measurement the illumination is 1 per cent of that which would be obtained if from that point the whole hemisphere of sky could be seen. Measurement is usually on a horizontal plane, for which a working plane height of 2 ft. 9 in. is assumed.

There are frequent references in this Report to daylight factors of 0·5, 1·0, and 2·0 per cent. It may be of interest, though generally unimportant, to know what actual illumination in foot-candles these and other values represent in terms of the British climate. This is shown on a table prepared for us by the National Physical Laboratory, and given in Appendix I.

THE DESIGN OF WINDOWS

21. The best approach to the design of windows is probably through a description of their lighting characteristics. Changes in illumination due to the different

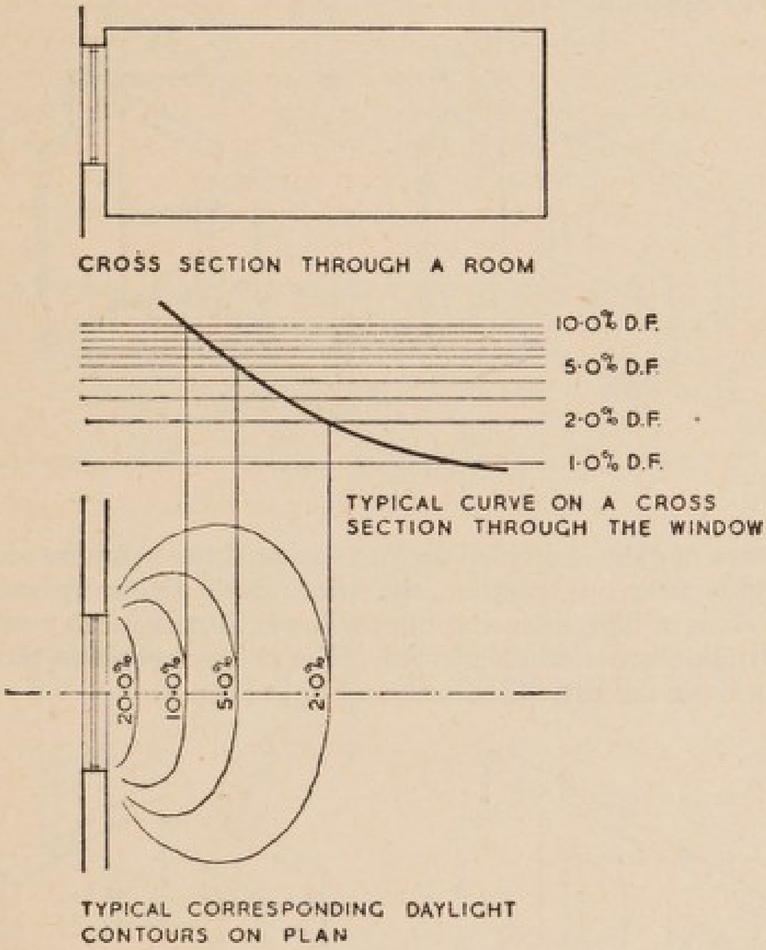


Fig. 2.

shapes, positions, and obstructions of windows all follow quite logical rules which, somewhat surprisingly, do not seem to have been described previously for designers. A knowledge of them alone ought to go far towards ensuring good design practice. In the following paragraphs, therefore, we attempt a picture of the performance of windows.

22. First the method of graphical presentation should be described.

Daylight coming through a window is represented on a cross-section drawing by a curve, the vertical scale for which is the daylight factor and the horizontal scale the penetration. In Fig. 2 a typical curve for unobstructed conditions is shown, taken on the centre line of the window. It begins high, at a daylight factor of 15 to 20 or 30 per cent, and drops in value quite smoothly as it moves into the room. Perhaps an idea of the order of the drop will be given by noting that with an unobstructed window 4 or 5 ft. square a daylight factor of 1 per cent would be found about 8 to 10 ft. inside the room.

On plan, the daylight distribution is shown by lines of equal illumination which are termed daylight contours. In the diagram four contours are shown, for values of 2 per cent, 5 per cent, 10 per cent, and 20 per cent. Obviously they correspond to the cross-section curve on the centre line of the window.

The contours of an unobstructed window are nearly elliptical.

23. When the shape of the window changes, the contour changes too. A long, low window gives a lengthy ellipse with poor penetration, while a very high window gives one which is more or less circular. Generally speaking, area for area of glass the high window is more efficient, giving rather more daylighted area within a given contour, and a decidedly greater penetration (Fig. 3). This point is discussed in some detail in Appendix IV.

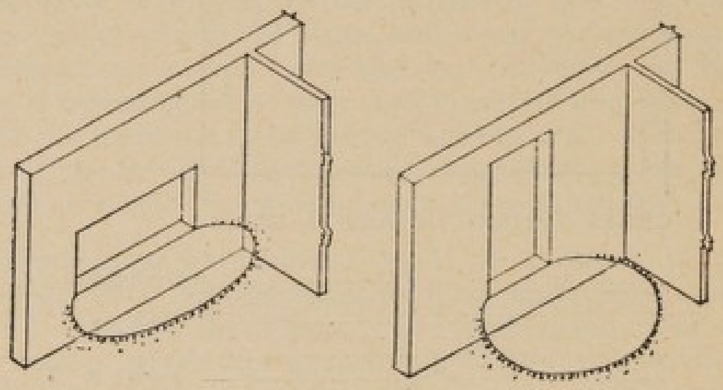


Fig. 3.

24. When an area of glass is divided up into two or three windows along one wall, spaced reasonably near one another, the effect is to divide up and reduce the penetration of areas of high intensity, but the lower illuminations generally overlap and their penetration is not much affected. The reduced peaks in the illumination values result in more uniform distribution of light (Fig. 4).

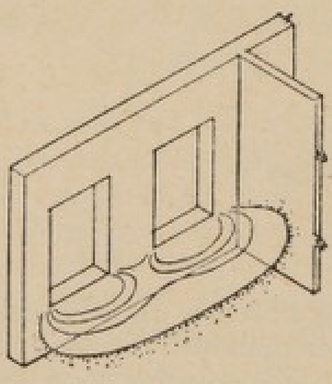


Fig. 4.

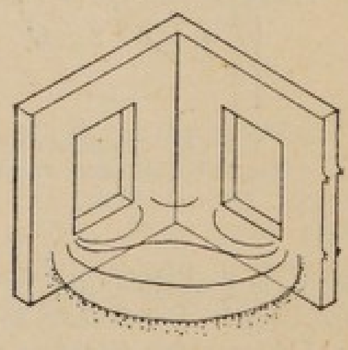


Fig. 5.

25. When these two windows are on different walls, at right angles to one another, the same generalization can be made; the areas of high intensity illumination near the windows are reduced both in value and area, as compared with a single large window, but the lower intensities overlap and their total area is often not much affected. The distribution of light is usually more uniform and the illumination of the walls will be improved (Fig. 5).

26. A corner window has an effect which might not be expected without a little thought. Within the area which is, as it were, enclosed by the window, the intensities are sharply increased because a far wider expanse of sky is visible. Outside this area, however, penetration is reduced, the illumination corresponds to what would be provided by a window across the opening, with a pointed hood overhead. The broken lines indicate a window across the opening, and the approximate position of the contour if that window was not obstructed by the hood. The solid line represents the contour of the window as shown (Fig. 6).

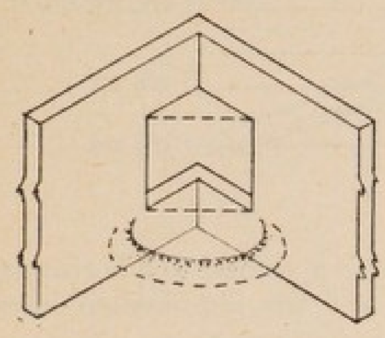


Fig. 6.

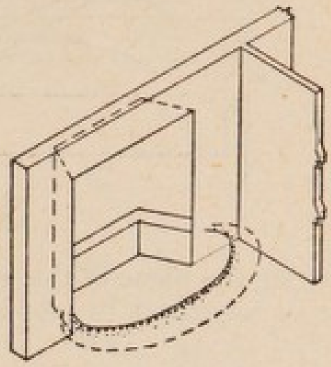


Fig. 7.

27. The ordinary bay window provides a corresponding effect. The illumination within the bay is very high, but the penetration into the remainder of the room is poor. The broken line indicates where this contour would have come had the window simply been across the opening. The bay is seen to be, by this comparison, an inefficient source of light for the room as a whole, for the glass area is much increased and the illumination of the main room area reduced (Fig. 7).

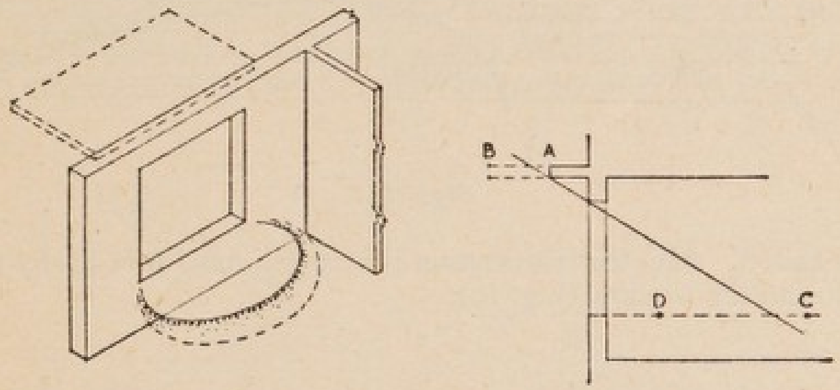


Fig. 8.

28. A contour of a window which is obstructed by a balcony overhead has a slightly reduced spread due to the fact that the obstruction continues either side of the window. Whether or not it effects penetration depends on whether from any given point in a room it adds to the obstruction of the sky. A hood may be designed to reduce intensities near the window without interfering with the light further inward. This is shown on the diagram; a projection to A would affect the light at D but not at C, while a projection to B would reduce the illumination at both points (Fig. 8).

29. When a window is raised so that its sill level is well above the working plane, the peak illumination on the working plane is lower, but the more distant values are improved. The sketch shows the same size window in three positions, and the

three resulting curves in cross-section. Clerestory lighting is an example from practice. In combination with other types of windows it often gives a very satisfactory quality of illumination even in rooms of domestic size (Fig. 9).

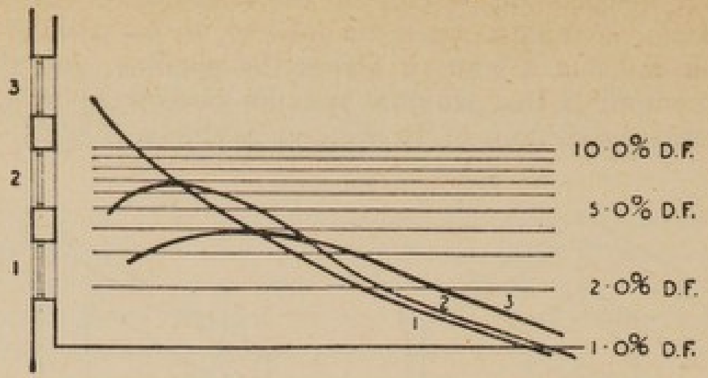


Fig. 9.

30. By changing the plane of the window from a vertical to a horizontal position, the exposure is increased by about twice, and the illumination intensities are

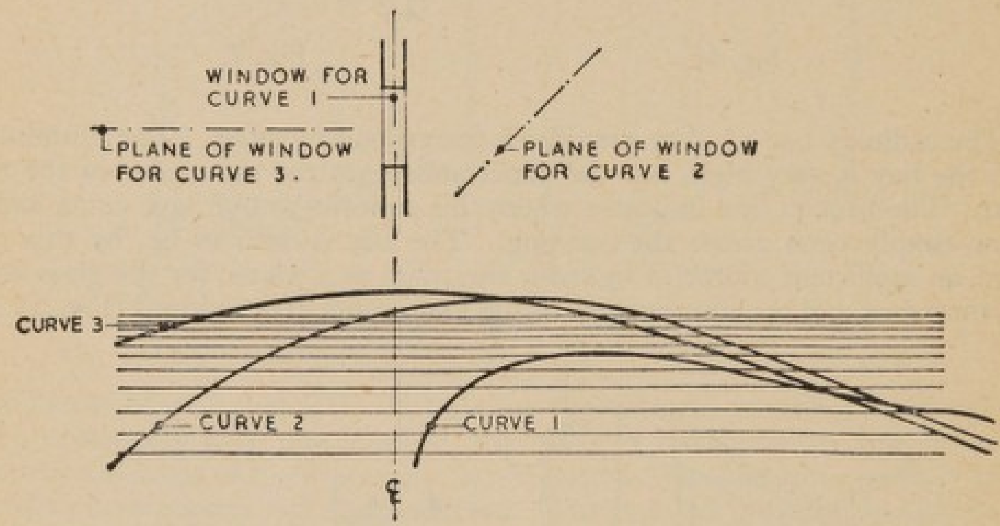


Fig. 10.

accordingly raised. Also the distribution is changed until it is finally quite symmetrical beneath the window (Fig. 10).

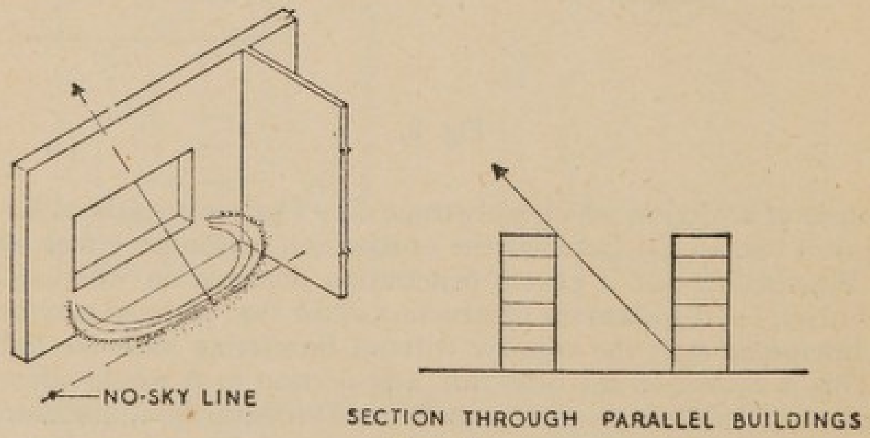


Fig. 11.

31. Obstructions have a marked effect on daylight illumination, and finally, of course, may cut it off altogether. If the obstruction has a horizontal sky-line—

as will be the case when, for instance, a continuous row of buildings stands opposite a window—then in cross-section the maximum penetration of daylight will be determined by a line through the top of the obstruction and the window head. Where this cuts the working plane a line can be drawn from beyond which no sky can be seen; this is termed the no-sky line, and for a parallel and horizontal obstruction, the no-sky line will be parallel to the window, as shown. Then all the daylight contours will come between this line and the window and those for the lowest values of illumination will nearly coincide with it (Fig. 11).

No-sky lines can be drawn for any shape of obstruction; only simple geometry is required to determine them.

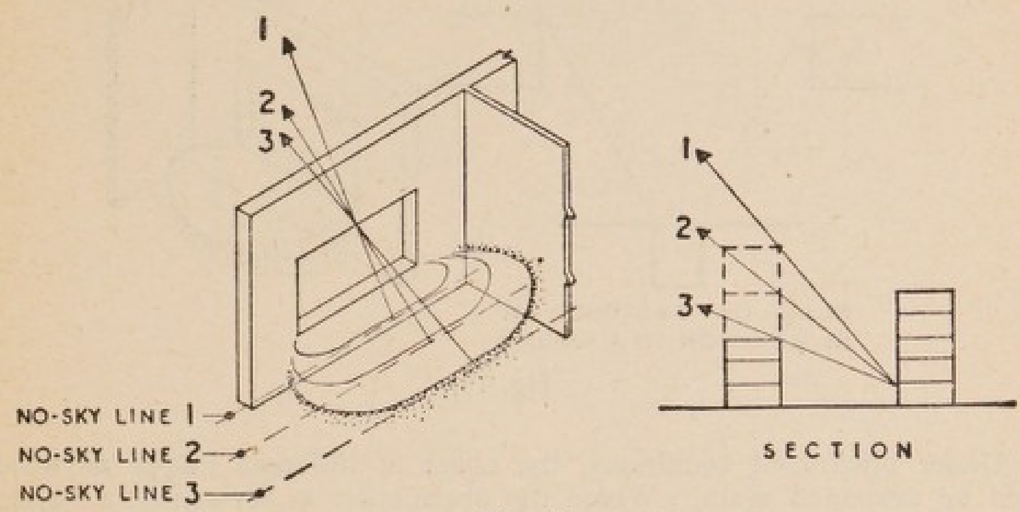


Fig. 12.

32. A horizontal and parallel obstruction more quickly affects the penetration than it does the spread of light. In Fig. 12 three contours are shown, one each for a different angle of obstruction, as indicated by the three no-sky lines. The penetration of the light is obviously sharply affected by the rising obstruction, but the ends of the areas enclosed by the contours are drawn in to a lesser extent.

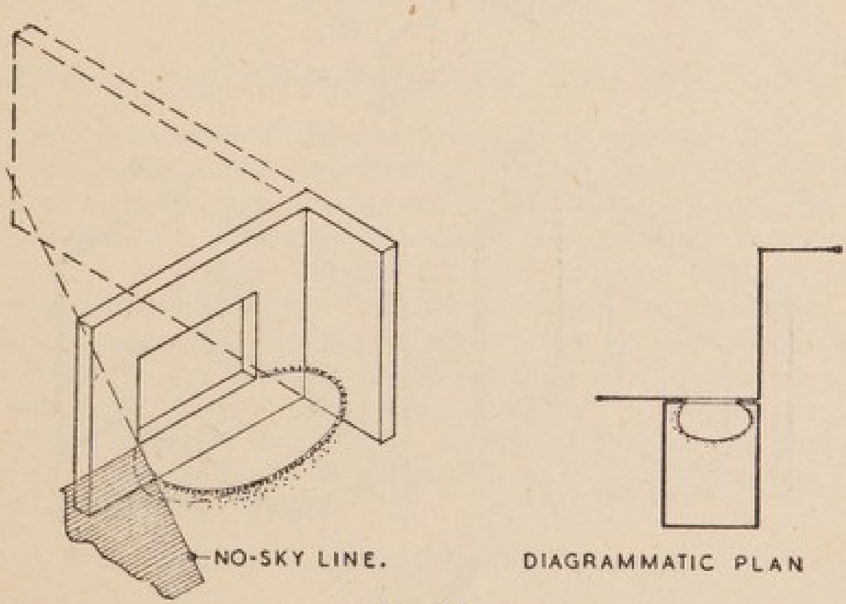


Fig. 13.

33. A vertical obstruction has the opposite effect. An external return wall is an example; penetration is not much reduced, but the spread of light on one side is cut off. In Fig. 13 two contours are shown, the solid one representing the obstructed

condition, and the broken one the unobstructed condition. The no-sky line is also indicated; it is, of course, in line with the outer edge of the return wall.

34. Two vertical obstructions between which a gap is left produce a result easily foreseen from the previous diagram. Penetration is still the less affected of the two dimensions, but the spread is cut down on both sides. The broken contour, as before, shows unobstructed conditions (Fig. 14).

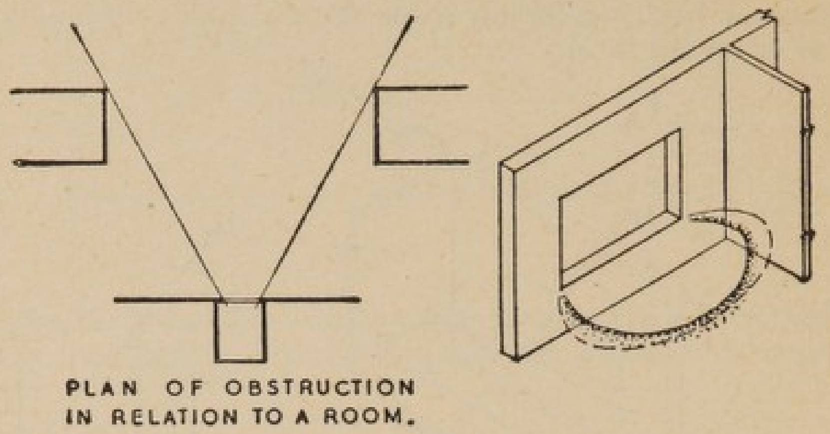


Fig. 14.

35. Under obstructed conditions, the effect of different shapes of windows should be examined again. Where the obstruction is horizontal, a horizontal window provides a long area of high illumination, with relatively poor penetration.

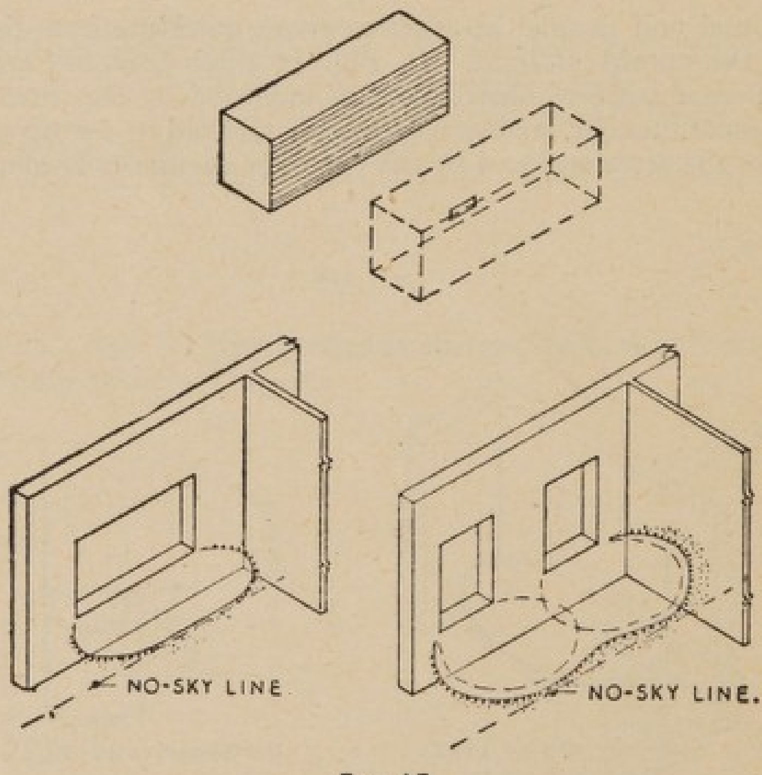


Fig. 15.

The same area of glazing, arranged as vertical windows, will give a better penetration and lower peak intensities. Spread remains quite good because of the long strip of sky visible. The result will usually be considered an improvement (Fig. 15).

36. If the obstructions are strongly vertical, with well-marked breaks in the sky-line, then the opposite effect can be expected. The vertical windows tend more to a demarcation of the light into rather strong beams across a room, whereas the horizontal window gives a more uniform illumination (Fig. 16).

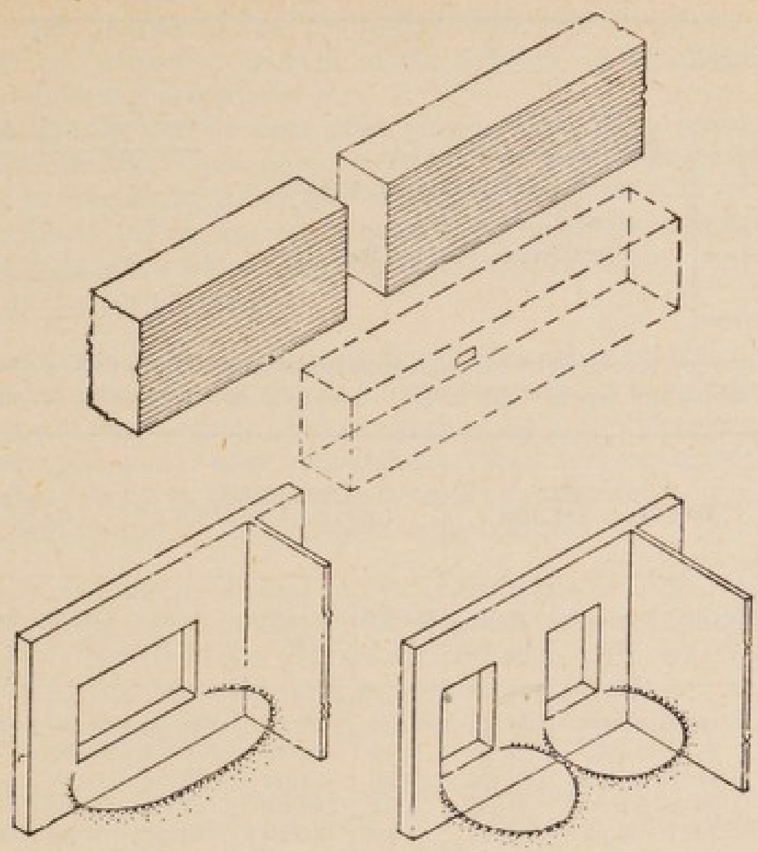


Fig. 16. DIAGRAM SHOWING GAP IN OBSTRUCTION AND POSITION OF WINDOW

METHODS OF ANALYSIS FOR WINDOW DESIGN

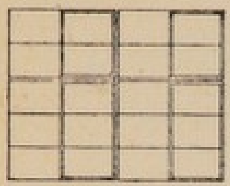
37. Although a knowledge of the characteristics of windows is in itself useful, we have been concerned to find some method by which the actual design of windows could be put on a rational basis throughout the building industry with little delay. We have considered the principal methods of analysis which existed before we began our work, as well as several new methods that have been submitted to us by the National Physical Laboratory and the Building Research Station. Although some of these are quite simple to use, nevertheless to make routine analysis of quite a few windows in a building would remain a tedious task, and take a fair amount of time. We finally arrived at a method which reduces the problem to very simple terms indeed. In brief, we propose to tabulate the performance of windows so that their design, so far as the amount of light is concerned, is merely a question of selection from Tables.

38. The National Physical Laboratory offered to prepare sample Tables for our consideration.

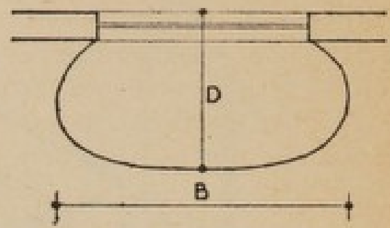
39. The first type of Table which would be for use in conjunction with standard windows gives the area within the contour and the depth and breadth of penetration for each of three daylight factors, 0·5 per cent, 1·0 per cent, 2·0 per cent, under five different degrees of obstruction ranging from 0°–60° at intervals of 15°. An allowance will be made for loss in light of the glass itself and due to

dirt. An example of the proposed type of Table is given in Fig. 17. We recommend that such Tables should be included in British Standards, and it is hoped that Tables of this kind will commend themselves to manufacturers as being suitable for inclusion in catalogues.

WINDOW TYPE
E2H/E2H
C2H/C2H



Overall dimensions :—
Height 5′ 1¼″, Width 6′ 6½″
Area 33·39 sq. ft.
Glass Area 25·16 sq. ft.



Allowance for loss of light through absorption, reflection, dirt, 20 per cent.
Values tabulated are for sill level. B and D are measured at sill level.

	2 PER CENT DAYLIGHT FACTOR			1 PER CENT DAYLIGHT FACTOR			0·5 PER CENT DAYLIGHT FACTOR		
Angle of Obstruction	Depth ft.	Breadth ft.	Area sq. ft.	Depth ft.	Breadth ft.	Area sq. ft.	Depth ft.	Breadth ft.	Area sq. ft.
0°	8·10	12·80	81·43	10·98	16·10	138·84	14·20	20·34	226·84
15°	7·35	12·50	72·16	9·42	15·76	116·60	11·60	19·74	179·84
30°	5·61	11·96	52·70	6·69	14·90	78·29	7·52	18·66	110·21
45°	3·79	11·10	33·04	4·34	13·80	47·04	4·68	16·86	61·97
60°	2·23	9·90	17·34	2·55	12·16	24·35	2·74	14·66	31·55

Fig. 17. TABLE OF CONTOUR DIMENSIONS
FOR VARIOUS DAYLIGHT FACTORS

The National Physical Laboratory is prepared to produce Tables of this kind at the request of manufacturers.

40. The second type of Table resembles the first, but is primarily for the use of designers. It would contain the same kind of information as the first type but the series would be in terms of a range of dimensions increasing by regular increments of 3 in. in height and 6 in. in width. The smaller height increment is used because the height of a window is more influential than the width in the lighting of rooms under normal conditions. The range would be big enough to cover all the normal needs of practice.

In the publication of these Tables the method of use would have to receive a brief description, and in that connection one point should be noted. The Tables, in the form shown, are in terms of five different degrees of obstruction. In the great majority of cases no difficulty should be found in deciding what the average height of obstruction is, or will be, in a given case; roof lines which do not vary by a total of more than about 20° can certainly be averaged without risk of appreciable error in practice, and by interpolation, the Tables ought then to give satisfactory results. When the obstruction varies more than about 20°, *i.e.* 10° either side of normal, then errors might become appreciable; wide and deep gaps in the obstruction, for instance, obviously would result in better illumination than an averaged figure for the obstruction would indicate, and similarly, a projection well above the surrounding sky-line would give an error in the opposite direction.

But how much effect either of these would have depends largely on their width. A gap or a projection with a width subtending 4° or 5° at the obstructed window would not have much effect on the illumination either way, but one which was, say, 15° to 18° wide would be considered substantial. Even so, however, we think that such Tables as we have in mind would enable a designer to choose a window which would meet the case unless the obstruction were so severe as to preclude useful daylighting. It would, in fact, in our opinion, be an exceptional instance which would require a full analysis.

The use of the Tables assumes that obstructions are a reasonable distance away: *e.g.* on the other side of a street. Very near obstructions subtending similar angles at the sill do not cut off so much light.

Bearing all this in mind, we recommend that the preparation of these Tables should be put in hand as soon as arrangements can be made, and that they then be published by the Department.

41. The third type of Table is, in a sense, the master-table. As a series, it contains a detailed tabulation of the illumination provided by windows of all sizes under all degrees of obstruction. As a permanent work of reference and an accurate method of analysis it would have considerable value, and we therefore recommend that it, too, be published as soon as this becomes possible.

This Table and its use are described in Appendix II.

42. We anticipate that the second of our three types of Table will satisfy most of the needs of designers, but there will be some types of buildings such as art galleries, hospitals, and factories where special cases arise which are best dealt with by individual analysis. For this purpose several methods are available, and we have examined them carefully. A full description of them will be found in Appendix II.

It seems to us that most designers will prefer a graphical method to a mathematical one, and of these, two have been tried in practice with some success. One is the well-known Waldram diagram, and the other the more recent daylight factor protractors produced by the Building Research Station.

The Waldram diagram has sometimes been regarded as a complicated method. We think this criticism is not justified and a description of its use is provided in Appendix II, which we hope will make its simplicity apparent. It can be used for very complex obstructions without difficulty.

The Building Research Station protractors are direct and obvious in use and have been well received by designers. They were developed to deal with the problem of war factory illumination. They are, in fact, very satisfactory for roof lighting analysis, but they also work quite well for general illumination problems, even of some complexity.

Both the Building Research Station and the National Physical Laboratory have submitted other methods of analysis, some or all of which may prove useful in practice or in special circumstances. It is impossible for us to assess their meirts fairly without adequate trial, and we therefore include a description of each in Appendix II to which we referred above. It is, in any case, desirable that some formal record of them should be made.

THE DESIGN AND SITING OF BUILDINGS FOR DAYLIGHT

43. In urban areas developed to relatively high densities, the design and siting of buildings closely controls the amount of daylight which has access to them. The design and siting of buildings is in turn related to the nature of the growth of towns. Therefore a brief reference to the way in which a busy town develops should help towards obtaining a clear picture of the lighting position, as it is to-day, in our cities.

44. Before the advent of lifts the height of buildings was fairly definitely limited by various practical considerations such as, for instance, the number of flights of stairs which people could reasonably be expected to climb. When the demand for accommodation in towns increased, most of the buildings were taken up to heights of this order, and frequently a position was ultimately reached where the available ground space was covered with buildings to a more or less uniform depth and density.

In such circumstances the natural lighting in buildings could not be generous. The sky-line as seen from the lower floors would be an almost unbroken horizontal line, and often at quite a high angle of elevation; in consequence the no-sky line would be distinct and the penetration of light much restricted.

Many towns which came to substantial size in the middle ages, and up to perhaps the eighteenth century, display this sort of development, and many examples still remain to be seen.

The introduction of the lift released new possibilities of heights and densities, a movement which was still actively continuing up till the outbreak of war, though in most cities some form of limitation on height, coverage, and angles of set-back was imposed to ensure that a certain minimum of light and air was preserved for occupants of buildings, and to keep down the fire risk. Regulations of this kind were fairly effective in preventing a further reduction in amenity and safety and often made possible marked improvements when older areas were rebuilt. They could not, however, secure what could be termed good daylighting without a substantial reduction in densities, a most difficult thing to accomplish, and not necessarily or wholly a desirable aim. The lighting in cities to-day remains, therefore, largely inadequate.

Where control of this kind is exercised, development is ultimately stabilized when the possibilities of accommodation under the restrictions have been exploited to the full, and it may be expected to remain static subsequently for lengthy periods. With this in mind, and in the realization that it will frequently mean the perpetuation of relatively poor conditions of natural lighting, the Committee, with the assistance of the Building Research Station, undertook a study of the factors in daylighting which influence the design and siting of buildings to find, if possible, some general principles upon which these modern problems of development could be reconciled with good daylighting.

45. The following are the principal variables of which account has to be taken in a study of this kind: the plan and layout, the height and spacing of buildings, and the overall density of development.

Density in this case means building bulk, and not, of course, the number of persons per acre. For the purpose of measuring building bulk, the ratio of the total floor space in the buildings to the total site area on which they stand seems the most reasonable basis. Beckett used this ratio in an early study of lighting problems,[1] and gave to it the term "floor space index," which we also have used. In many cases the index will simply be the coverage multiplied by the number of floors.

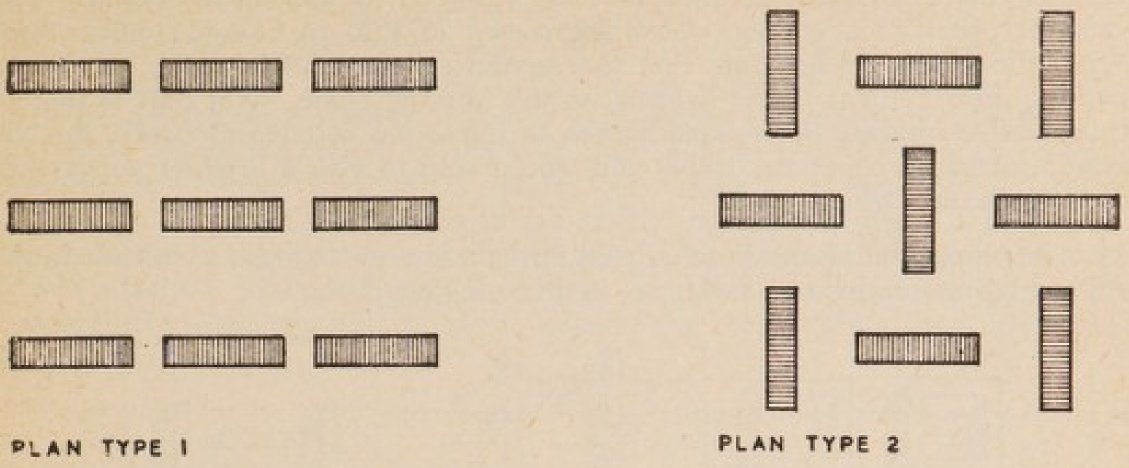
PLAN AND LAYOUT

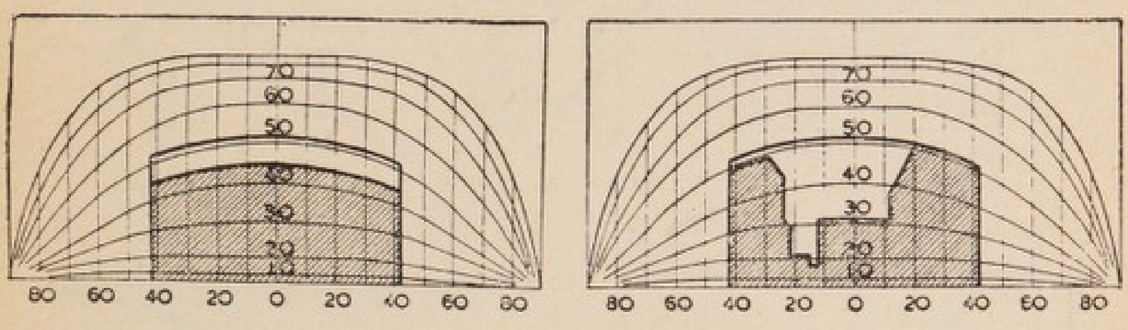
46. The most significant factors in the provision of daylight are variations in the planning and layout of buildings. The order of improvements possible can be demonstrated by the following simple example from which, also, certain deductions of importance can be drawn.

The example consists of a comparison of simple rectangular buildings arranged

[1] Beckett, H. E., "Population Densities and the Heights of Buildings," *Transactions of the Illuminating Engineering Society*, July 1942, p. 75.

in two ways, first with the units parallel to one another, and second, with every alternate building lying at right angles to its neighbours. In each case the size of the units, *i.e.* their length, width, and height, are kept the same, and also the spacing of them centre to centre. The two arrangements are shown in Fig. 18.





WALDRAM DIAGRAMS SHOWING SKY-LINES RESULTING RESPECTIVELY FROM THE TWO LAYOUTS AS SEEN THROUGH TWO TYPICAL WINDOWS ON THE GROUND FLOOR

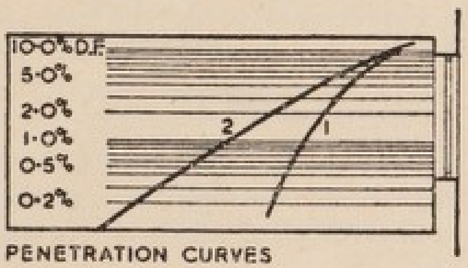


Fig. 18.

It will be clear, from a brief consideration of the layouts, that the profile of the sky-line as seen from rooms on lower floors will be very different in the two cases. The first will be a virtually continuous horizontal line, and the other will be broken by large gaps. The differences can probably best be demonstrated by diagrams of the sky-lines as seen through a window. Shown beneath the two layouts are the Waldram diagrams giving views of the respective sky-lines as seen through typical windows. The serrated character of the second as compared with the unbroken line of the first stands out clearly. It can be imagined that the eye is at working plane level and fairly near the window. The curvature of the window head and the building is a characteristic of the diagrammatic representation and does not represent a real curvature.

The important point is to note that in the second diagram showing the serrated sky-line an area of sky has become visible at a much lower angle than formerly and its light will be able to penetrate correspondingly deeper into the rooms. One would also expect to find some slight loss of light near the window, but the intensity there is usually so great that small differences are not noticeable. The daylight penetration curves, which are shown in Fig. 19 below, confirm these expectations and demonstrate that the second arrangement provides, in fact, a striking improvement in the lighting on the working plane. Not only is there a considerable increase in the area lighted to intensities suitable for work, but the lower intensities penetrate deeply and would help to give a brighter appearance to the room as a whole.

47. A comparison of certain other plan forms was made in order to include in the study a representative range of types for planning purposes.

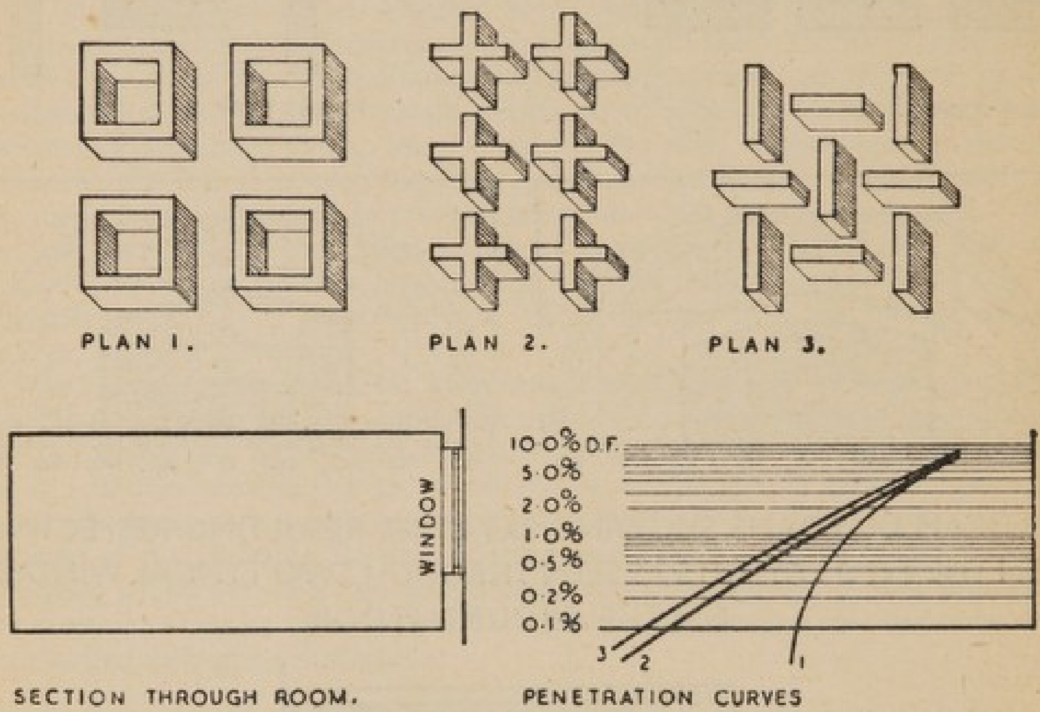


Fig. 19.

The basis for comparison in this second series is a type which is widely characteristic of contemporary urban development, *i.e.* the hollow ring or square. The second type is the cruciform plan, which is representative also of variations such as the "T" or the "L."

Finally, in order to relate this series to the previous one, the arrangements of simple rectangular buildings at right angles to one another is included.

The three arrangements are illustrated in Fig. 19. All buildings are assumed to have equal height, and to represent equal densities. The spacing and lateral dimensions of the buildings are adjusted accordingly. The daylight penetration curves for typical ground floor rooms in each type are also given, the curve for the hollow square being an average of two curves, one for a room facing inward to the enclosed square and the other outward to the street. The curves demonstrate that the cruciform plan and the arrangement of buildings at right angles are equivalent in the daylight provided, whereas the hollow square offers a much lower standard, corresponding to the parallel arrangement of buildings in the first series.

48. It will be generally understood that the improved lighting of the best arrangements is a result of their more open character, but it is desirable to refer to the

source of improvement in detail, so that designers will have a more precise appreciation of the factors involved.

In the first place the improvement of the open plans is due to the fact that the main obstructing elements of the buildings are further away from the windows concerned than in the less well-lighted schemes. This enables the angles of obstruction to be reduced. For instance, of the two arrangements shown in Fig. 20, "B" is preferable to "A" from the lighting point of view for this reason.

In the second place the gap which is left between the obstructing buildings is important, being the source of the very low angle light which has the deepest penetration. Where possible, therefore, gaps should be arranged at suitable intervals in the layout. Suitability in this respect refers to their relationship to the windows which the light is intended to enter. To be useful the gap has to be within a limited horizontal angle from these windows; otherwise the light which comes through the gap will go to the sides of the rooms rather than penetrating towards the back.

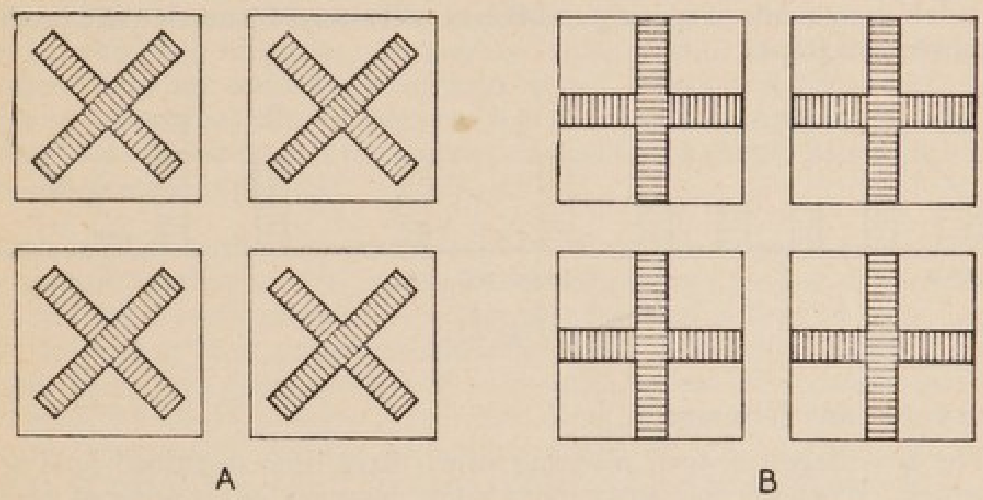


Fig. 20.

No precise limit can be given for this horizontal angle, for it depends partly on the size of the windows. If these are wide, for instance, then wider angular limits are acceptable than with narrow windows. In the cruciform designs shown, the gaps between the nearest obstructing buildings occur at angles of deviation not more than 20° from the worst lighted window; *i.e.* within 20° of a line normal to the window. The latter was 10 ft. wide in all cases. It seems likely that angles of deviation up to 25° would prove suitable in many cases.

HEIGHT AND SPACING OF BUILDINGS

49. In the two series of studies which have been described height was kept constant in order to reduce the number of variables. In a third series the plan form was altered from hollow square to the cruciform and finally to the rectangular units at right angles as before, but the lateral dimensions and spacing were kept constant and the height was allowed to vary to keep the floor space index constant. Thus, with an index of two, a hollow square with sides 200 ft. long was nine storeys high, and the cruciform with arms measuring 200 ft. from the tip to tip had 14 storeys. The result corresponded closely with those which have been given in paragraph 47 for the same plan forms at a constant height, which indicates that the plan form is the main factor. It shows equally, however, that increases of height associated with appropriate plan types are not themselves disadvantageous to daylighting. Ultimately with higher densities increased heights become necessary. Otherwise, even the better types of plan may spread so much that some of the advantages are lost.

50. In another series of studies the plan form and unit size was kept constant, the latter at 200 ft. as above, but the spacing was increased from 200 ft. through to 500 ft., and the height of the buildings was allowed to increase to maintain the density. With a floor space index of 2, no appreciable improvement appeared to result from the increased spacing, but at an index of 3, penetrations improved up to a spacing of about 350 ft., and it may be conjectured that at higher densities greater spacings still would be advantageous; at least so far as daylighting alone is concerned. It would be desirable to confirm this with further studies, though its interest is largely academic.

51. Where parallel buildings alone are concerned, increased spacing—with corresponding increases in height to keep the floor space index constant—causes a useful improvement, and reference may be made here to previous researches by Gropius [1] and Beckett (*op. cit.*). The effect is apparent in the cross-section diagram (Fig. 21), where the angle of obstruction decreases as the spacing increases. It will be observed, however, that the change from A to B is greater than from B to C; the first few increments of spacing and height will always be much more productive than subsequent steps

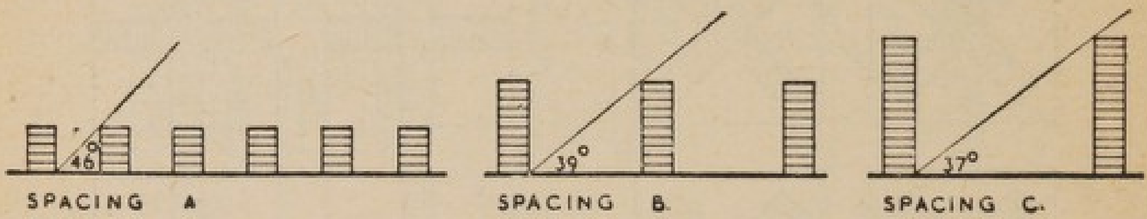


Fig. 21.

DENSITY OF DEVELOPMENT

52. The advantages of open planning which have been described hold true at all densities. When the floor space index is low, however, of the order of ·75 to 1·0, angles of light may be as low as 15° on the average and acceptable lighting for many purposes can then be obtained. Developments with floor space indices exceeding, say, 1·25, would generally benefit materially from the open plan forms.

OPTIMUM SIZE AND SPACING OF UNITS

53. It would be desirable at this point to be able to give maximum sizes and spacing of building units to produce the best daylighting, but accurate and precise recommendations would require more study than could be given to the problem at present. We will therefore limit ourselves to the remark that units of about 200 ft. in extreme lateral dimension, and with a spacing, centre to centre, of 250 to 300 ft., will give the best conditions at densities which appear to prevail at present in English cities, while increases in spacing would be desirable for densities which are much higher.

Where open plan forms of the above size and spacing are used no difficulty should be found in securing the penetration of at least moderate values of daylight to depths of 15 or 20 ft. in the ground floors, at densities as high or higher than those prevailing to-day. These figures compare very favourably with present conditions.

RELATION OF PROPOSALS TO EXISTING CONDITIONS

54. Some data have been collected regarding typical densities in urban districts in order to relate this work to existing conditions in cities.

[1] Gropius, W., *The New Architecture and the Bauhaus*, p. 71 et seq. Faber and Faber, 1935.

For the City of London a rough calculation suggested that the total floor space index was slightly higher than 2. A much closer estimate of one district in Hull also gave a figure of 2, but there the heights of buildings were less than in London, and streets occupied a higher percentage of total ground area.

55. The floor space index in the City of London had not become stabilized in any sense before the war. The average height of buildings in London was well below the allowable limits and the demand for accommodation exceeded supply. New buildings were therefore often exploiting the full possibilities of accommodation permitted within the limits of height and set-back. Isolated examples showed that in such cases densities of 4 or more were reached, which appears to indicate that, unless some other control is exercised, the City's population may ultimately double itself.

One of the factors limiting the demand for accommodation is inaccessibility of otherwise popular areas. It is certainly conceivable that, with the increased accessibility due to widened streets, there will be a renewed demand for space in buildings after the war which will be reflected by generally higher floor space indices in rebuilding schemes. An average index of 3 for large parts of the City of London seems not unlikely in ten years' time. This possibility, which may be common to other cities which have received widespread damage in the war, lends urgency to the suggestion that the more open plan forms should find their way into general use as soon as possible.

56. One point of cardinal importance follows from this suggestion.

The typical "hollow square" arrangement of buildings around the periphery of a block of land is often related to the fact that the land is held by many separate owners developing their properties independently. A cruciform arrangement or any other open plan form would not be possible unless one could visualize the comprehensive redevelopment of larger land units at one time. We therefore urge upon those responsible for the broad foundation of planning the serious consideration of this factor, which drives to the root of the problem, at least so far as the immediate redevelopment of war-damaged areas is concerned.

57. In areas which are largely undamaged, and where rebuilding will therefore be a relatively slow process, it is nevertheless important to foresee and direct the change to open plan types, for even one individual development of this kind at once acquires for itself a large part of the benefits which can ultimately be obtained from the widespread use of open plans. The classic example in this country is no doubt the London Passenger Transport Board's building at No. 55 Broadway, in London. It is a cruciform plan in the midst of a congested development of the more usual hollow square arrangements, and the lighting is notably improved.

58. We were glad to observe, in the published official proposals for the re-planning of London, that there is a tendency to avoid closed light wells. The resulting more open character of the streets should benefit both the direct daylight, in the way described in this Report, and reflected light as well since this, too, is greatly improved by open planning.

59. It seems to us that developments of open planning have a further material advantage in the release of ground space for other purposes. At present some 30 per cent of the City of London is devoted to streets, and in one district of Hull which has been examined the road area was over 40 per cent of the total. In each case, of course, the road system is archaic, and the same area would probably serve modern needs much better in some other form. But bearing in mind the tendency to increasing accommodation which accompanies improved accessibility, and also the severely limited parking facilities at present available, it is clear that the land devoted to streets must be used more efficiently.

60. These are the main points emerging from the analysis which was made for the Committee. We need not further elaborate them, for their significance will be apparent to those who are familiar with problems of urban development. We would like, however, to discuss what seems to us the fundamental point which has been clarified by the study. If we continue, in this country, to emphasize the generally horizontal development which has characterized our town design up till now, we cannot hope for good daylighting in urban buildings unless an effective restriction is placed on the total density in a given area. Low densities may be reasonable and possible in new towns and should be considered, but in existing cities their introduction would require a substantial reversal of present trends and one which would need much thought on the part of the authorities. Therefore it is of value to be able to record that if those of our city buildings which merit good daylighting can be given the characteristics which have been outlined here, densities of the present order, and, indeed, considerably higher densities, can be accommodated with good natural illumination. *We therefore recommend that the general shape, height, and spacing of buildings as they affect daylight illumination shall be taken into account as factors in site development and town planning.*

METHODS OF MEASUREMENT AND PRINCIPLES OF DESIGN FOR SUNLIGHT

THE ANALYSIS OF SUNLIGHTING

61. The path of the sun in the sky at different times of the year is so definite that it might appear at first sight a relatively simple matter to take it into account in planning buildings. However, design is rarely a sufficiently straightforward affair for this to be the case, and methods of analysis have been found necessary for the solution of many problems. We have considered the various methods which have from time to time been proposed, and it appears to us that two at least are suitable for general use. These are: (1) the Burnett diagrams and (2) the Heliodon. A description of each will be found in Appendix III. There are other methods available, some of which may be equally useful in practice; they are described in the R.I.B.A. Report on the Orientation of Buildings.[1]

62. The method developed by Burnett consists of two diagrams, one showing graphically the position of the sun on plan at different times of day and seasons of the year and the other showing the altitude of the sun. The diagrams are used beneath tracing paper, and by their aid it can be quickly seen whether or not sunlight will penetrate a given window. The method is direct, inexpensive, and very attractive for general use by designers.

63. The Heliodon was developed some years ago at the Building Research Station.[2] In essence it consists of a table, adjustable to represent the movement of the earth, and a light source to represent the sun. Analysis is made with models, and large schemes can be examined without difficulty. It should be useful in the bigger offices but may be regarded as having a more important place in the equipment of planning authorities and schools of architecture.

64. It is interesting to note that, when the Heliodon is used and plastic models are employed, an attitude to design is developed which can probably best be described as "the sculptor's approach," and to architects this often has a significant value.

[1] *The Orientation of Buildings*, Royal Institute of British Architects, 1933.
[2] A. F. Dufton and H. E. Beckett, "The Heliodon, an Instrument for Demonstrating the Apparent Motion of the Sun," *Journal of Scientific Instruments*, 1932, 9 (8), 251.

THE DESIGN AND SITING OF BUILDINGS FOR SUNLIGHT

THE SUNLIGHTING OF INTERIORS

65. A number of reasons are given from time to time as to why sunlight within a building is desirable. Some of these may be important, but we think that the most significant argument for adequate sunlighting is the evident desire of the people to have it.

If a window is to permit the entry of sunlight two conditions must be satisfied:

a. The window must be oriented within certain limits.

b. It must not be obstructed so that sun cannot reach the window.

66. The determination of acceptable limits of orientation for windows will depend upon the time of day when sunlight is wanted, whether it be morning, noon, or afternoon, and upon the time of year with which one is concerned.

67. To illustrate the approach to this part of the problem, it is convenient to take the case of winter sunshine. The horizontal range of the sun in midwinter is only about 90°, from south-east to south-west. If a window is in a thin wall, the extreme limits of orientation which would permit any penetration of sunlight would then be the other 270° from north-east to north-west, as indicated in Fig. 22. In practice some allowance would have to be made for a cut-off due to the depth of window reveal, and this would reduce the limits of orientation to about east-north-east and west-north-west, a range of about 225°. This range can be further subdivided for morning or afternoon sun.

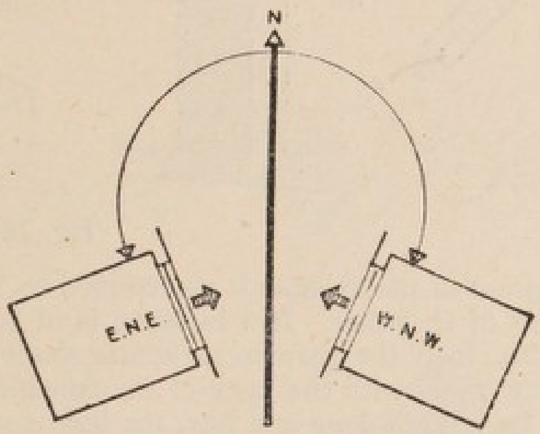


Fig. 22. DIAGRAM SHOWING TWO ROOMS AT THE EXTREME LIMITS OF ORIENTATION TO RECEIVE WINTER SUN

68. A similar approach may be used to consider sunshine at the equinoxes or at any other time of year, and it is desirable that designers should be so familiar with the movement of the sun that they can readily apply their knowledge to planning problems. However, this can form only a first guide to design, and designers will often wish to have more detailed information, especially about the comparative efficiencies of windows at different orientations for the admission of sunshine in terms of the whole year. A discussion of this aspect of the problem will be found in Appendix III. It is shown there that, if the sun at all seasons is considered, a building with four exposed faces, unobstructed, will be most equitably sunlighted if its orientation is east-north-east, west-south-west, south-south-east, and north-north-west. An orientation of north-east, south-west, south-east, and north-west is almost equally good. A building with windows on two sides only (such as terraced housing) can best face east-south-east, west-north-west, though east-west is also good. A master-graph is attached by means of which a designer, having

taken the altitude of obstruction for the main directions on the site, can compare all possible orientations and select the best.

THE SUNLIGHTING OF THE GROUND AROUND BUILDINGS

69. Sunlight on the ground around buildings is useful in a number of ways. The reflected light is a most attractive amenity, and sunlight is, of course, essential for the maintenance of vegetation. It probably helps, too, to keep the areas around the buildings clean, and can also be used as an index of the shadowing of neighbouring buildings.

70. It is again convenient to consider the problem first in terms of winter conditions, recognizing that at other times of year both the sweep of sun and its angles of elevation are more generous.

71. The first illustrations will be based on a simple rectangular plan. If the sun in winter performs a sweep of 90°, then a plan of this type may be oriented with its axes lying north-east and south-west, or vice versa, and the ground round about it will receive sunshine at some time of day all the year round. This will be clear from Fig. 23. Any other orientation will result in a certain amount of shadowed area in winter.

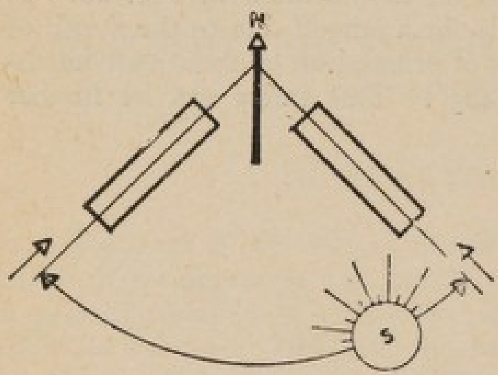


Fig. 23.

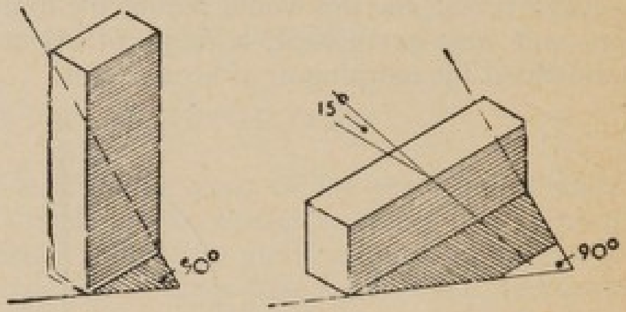


Fig. 24.

72. The shape and extent of the shadow is determined by the sweep of the sun and its maximum angle of elevation. If a building is of considerable height in comparison to its width, then the permanent winter shadow area will take the shape of a right-angle triangle with the apex of the triangle being 90°. On the other hand, when the building is long and low, the light coming over the top of it at an angle of 15° will truncate the triangle. It will be evident that as the proportions of a building (as seen from the north) are altered from the horizontal to the vertical, the area which is shadowed in winter will become reduced. The extent of the reduction for a typical case can be judged from Fig. 24.

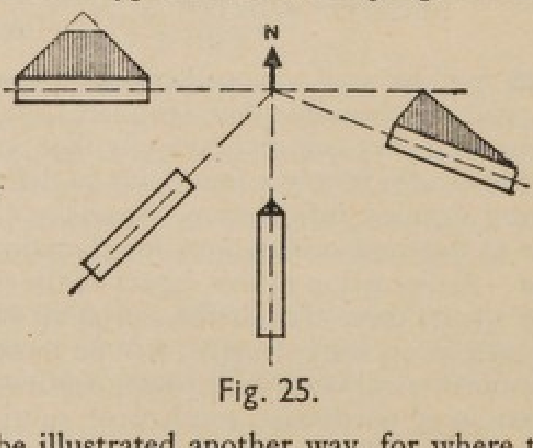


Fig. 25.

73. The point may be illustrated another way, for where the aim is to keep the winter shadowing small, the major axis of general rectangular buildings should not lie much beyond a line running north-east and south-west, or vice versa.

Towards the east-west orientation, as shown in Fig. 25, the proportions of the northerly façade become such that winter shadowing is developed to a maximum.

74. Some emphasis may be laid on the use of winter shadowing as a criterion for the insolation of the ground, not so much because winter conditions are the only ones that matter, but because it is more convenient to compare these "fixed" shadows than the transient ones which move across the ground. At the equinoxes, for instance, the sweep of the sun being a full 180°, there will be no areas which do not receive sun around the simpler types of plan, and the basis of comparison becomes more complex.

75. In the above paragraphs we are concerned with sunlight in the interiors of buildings or immediately around them. We have not forgotten the satisfaction of a view on to a pleasantly sunlit scene, but we regard this as of lesser importance than the other objectives noted.

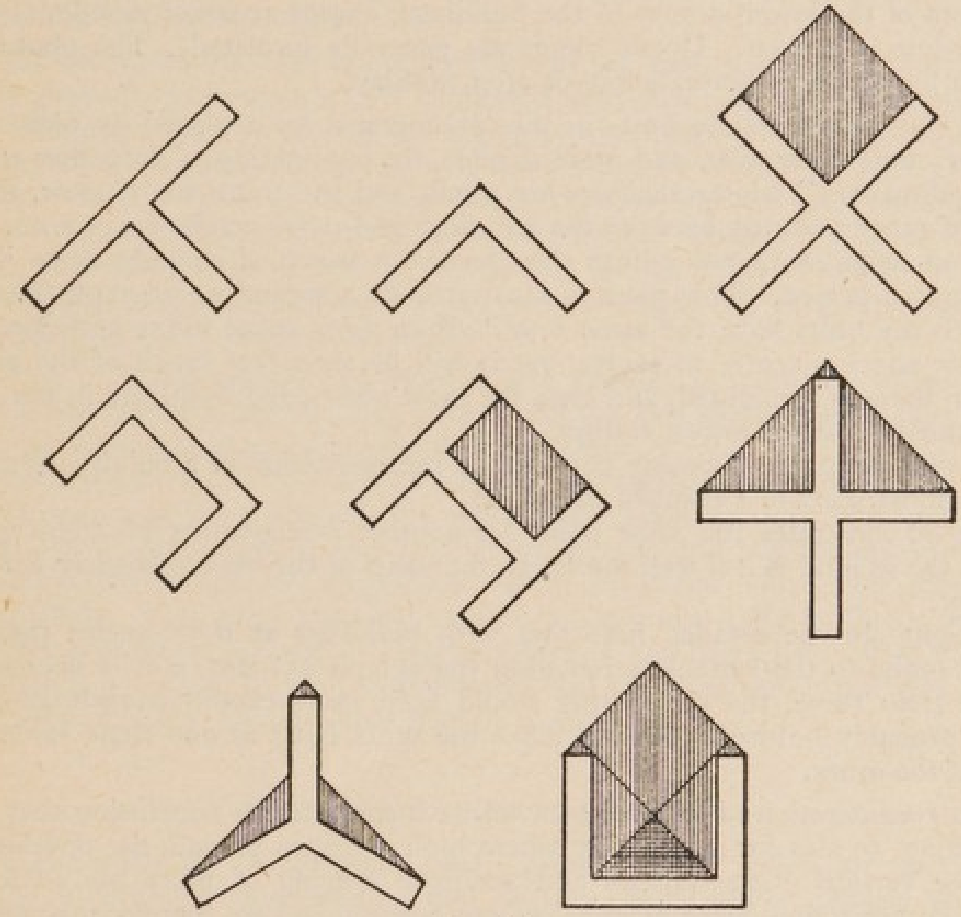


Fig. 26.

ALTERNATIVE PLAN TYPES AND ARRANGEMENTS OF BUILDINGS

76. Buildings of more complicated plan types may be examined for the most part as developments from the rectangle.

77. Two or three rectangles may be put together in several variant forms such as the L, the T, the U, and the cruciform. So far as the L, the T, and the U are concerned, they are best oriented south-east and north-west, or vice versa, when they will cause no winter shadowing. The cruciform arrangement is disadvantageous in this respect, as is the "H" type plan. Any arrangement which involves a recess on a northerly face will result in shadowing, even up to the time of the equinoxes, and, if the recess is deep enough, there will be an area which receives no sun at any time of year, as indicated in one of the diagrams in Fig. 26. Deep recesses on the northerly façades should be avoided if at all possible

Since the cruciform building type was mentioned in connection with daylighting, it should be noted that an L or T arrangement would be equally satisfactory as a general plan type for that purpose. There is thus no conflict between the requirements of daylight and sunlight in this respect.

THE MUTUAL SHADOWING OF BUILDINGS

78. It has been observed that the dominantly horizontal types of building cast more extensive winter shadows than do taller, more slender units, and it is to be expected, therefore, that where buildings of this type are grouped together, their shadows will affect one another. The point may be illustrated by a photograph, Plate 8A, of models on the Heliodon. The development is representative, in general type and density, of that which is found in our urban districts, except that the street proportions are rather more favourable than usual to sunlighting. It will be seen that the whole of the ground area between the buildings is shadowed and also most of the lower storeys of the buildings, except at street junctions, where the sky-line is broken. Upper rooms are generally insolated. The photograph is taken for about 1½ hours before or after midday.

79. If the hollow square units in this photograph are replaced by ones which are characteristically taller and more slender, the sunlighting is altogether altered. The "permanent" winter shadows are small, and the transients narrow, so that shafts of sunshine break between the buildings and move across the ground. The storeys of neighbouring buildings then receive a sweep of sunlight, even if only for a limited period. This point is illustrated by a second photograph (Plate 8B) in which the units have the same total bulk or floor space index as before, and the same spacing centre to centre, yet it will be seen that much of the ground between them is sunlighted, and even the most obstructed buildings in the group are in sunshine at the lowest storeys.

The photograph is obviously not a literal representation of a building type, but only an illustration of a point of principle.

Plate 8C illustrates the same point for another arrangement of building, and though the ground is less well insolated, the value of the broken shadow is readily apparent.

It might also be recalled here that with buildings at right angles there are narrow limits to the suitable orientation (paragraph 73) and, if it is necessary to deviate from these, the sunlighting would need more careful consideration. It would probably be useful then to make the units lying at one angle lower than those at the other.

80. In consideration of these factors we have come to the conclusion that as for daylighting, so also for sunlighting where high densities prevail, the development with the vertical characteristics and adequate spacing of units has advantages which the horizontal development does not possess, and we therefore recommend that they be taken into account as factors in site development and town planning.

81. Another point may be deduced from Plate 8C. The total pattern of shadow tends to close up or clog when the shadows from individual units overlap. The clogging need not occur seriously, however, if the number of units is limited. It follows, then, that for a high overall density, local concentrations of accommodation would often give better results than distribution in many separate units.

THE DIRECTION OF STREETS

82. We base our views about the desirable orientation for streets largely on the requirements of the buildings which line them.

An east-west orientation will obviously be generally unfavourable. Where there is a grid, then something approaching the diagonal orientation is the best solution. If the arrangement has long, dominant arteries, then these should be set out in some orientation between south-east and south-west.

83. Many factors enter into the decision of where to place a street and we do not wish to over-emphasize orientation. At the same time, where unfavourable orientations have to be adopted it would be undesirable to attempt to canalize the buildings into the same line to their own detriment. In the end it is they which matter most, and street design should take this into account.

METHODS OF MEASUREMENT AND PRINCIPLES OF DESIGN FOR ARTIFICIAL LIGHT

SOURCES OF LIGHT

84. Artificial light sources in most general use in this country at present are electric lamps, both of the incandescent and discharge types, and gas mantles of the high and low pressure types.

85. The colour of the light emitted except in the case of the electric discharge lamp is generally somewhat yellow compared with daylight, but the whole range of the visible spectrum is present in varying proportions. Thus, while all colours are revealed, the colour rendering will not always be similar to that given by daylight. Certain types of discharge lamps such as high pressure mercury and sodium types emit light deficient in some colours and should only be used where their special characteristics are no drawback. As an offset to their colour deficiencies such lamps are of high efficiency and the light has been found specially suitable for many industrial processes.

86. Most of these sources are small in size in relation to their light output, a characteristic which lends itself to optical control, but which means they are so bright that they can cause glare unless shielded from view.

Special mention must be made of tubular fluorescent electric discharge lamps. High-voltage types were available for some years before the war: the low-voltage type has only been in use in this country since 1940 and has consequently been used almost exclusively for installations of an industrial nature connected with the war effort. It is likely that these lamps will exercise a big influence on post-war lighting practice because of their qualities of low brightness, large area and high efficiency, combined with wide possibilities of colour control to give almost any approximation to daylight that may be required.

UNITS OF MEASUREMENT

87. Words such as "brightness" and "illumination," which are used quite generally in ordinary conversation and writing, have also a definite technical meaning, and it is therefore desirable to give here a brief explanation of these terms and of others used in illuminating engineering.

88. A source of light emits something that affects our eyes. That something, when we are speaking quite generally, we call "light." When, however, we wish to be more specific and to make quantitative statements we use the term "luminous flux" as this indicates that what our eyes appreciate as light is, in fact, a continuous *flow* of energy of a particular kind. This luminous flux is measured in units called "lumens." One lumen is the amount of light flux emitted from a standard candle on to an area of one square foot, every part of which is one foot distance from the candle.

89. These terms can, perhaps, be best explained by imagining a light source placed at the centre of a sphere. If this light source is perfectly uniform, *i.e.* if it has the same candle-power in all directions, the luminous flux it emits will naturally radiate uniformly and every unit of area of the surface of the sphere

will receive the same amount. The illumination of a surface is measured by the luminous flux reaching it per unit area. In this country the unit of illumination is the foot-candle, defined as the illumination which results when one lumen is uniformly distributed over one square foot. Referring to Fig. 27, it will be seen

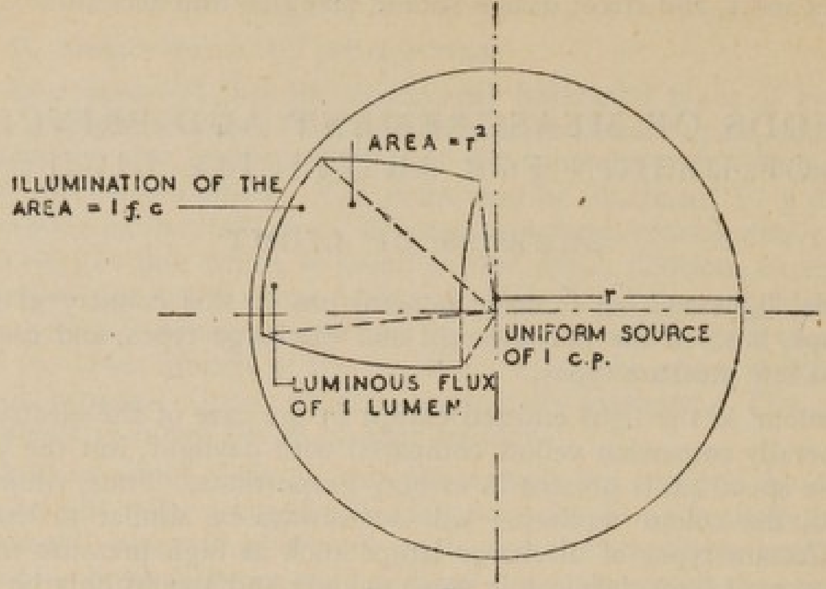


Fig. 27.

that if the radius of the sphere is one foot, and the candle-power of the source is one candle, the luminous flux reaching one square foot of the spherical surface is one lumen, so that, on the definition given above, the illumination of the spherical surface is one foot-candle. Actual light sources have not the same candle-power in all directions and the illumination of the spherical surface will then not be uniform; in fact the illumination of any given area will be proportional to the candle-power of the source in the direction of that area.

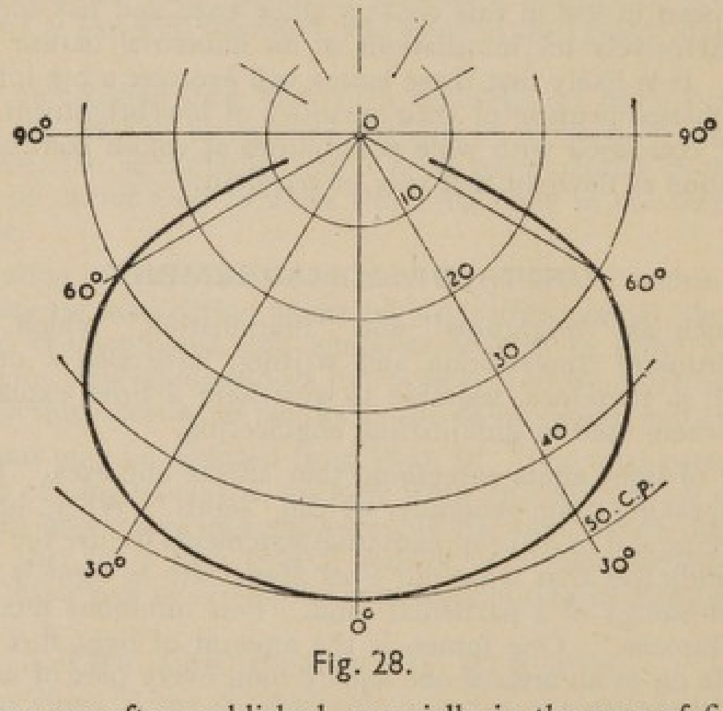


Fig. 28.

90. Polar curves are often published, especially in the case of fittings, to show graphically how the candle-power of the fitting varies. Unless otherwise stated, it is assumed that the fitting is symmetrical about its vertical axis, so that one curve serves for all vertical planes passing through the centre of the fitting. Fig. 28 shows such a curve, and from this it will be seen that (*a*) the candle-power in the

vertically downward direction is 50, and (*b*) the candle-power diminishes rapidly (*i.e.* there is a fairly sharp "cut-off") at about 60° from the downward vertical.

91. The brightness of objects lit is a measure of the light reflected back by them and is, therefore, a function not only of the illumination falling on the object, but also of its reflection factor. This brightness is measured in terms of equivalent foot-candles, *e.g.* the brightness of an object having a reflection factor of 50 per cent, and receiving an illumination of 10 foot-candles, would be 5 equivalent foot-candles.

A different unit is used when measuring the brightness of light sources. In this case a small area of the source is regarded as equivalent to a source of given candle-power which is measured by dividing the total candle-power of the source by the area of its radiating surface; in this Report this is generally expressed as candles per sq. in. For conversion purposes 1 candle per sq. in.=452 equivalent foot-candles.

METHODS OF DESIGN

92. The illumination over any given area is determined by the total lumens spread over the area. The lumen output of all light sources in general use is indicated by the maker and is frequently covered by British Standards, but there are many factors which go to determine how many of the lumens which emerge from the original source reach any particular surface. In the first place, if the lamp is enclosed, as is usually the case, in some sort of fitting, then part of the light will be obstructed or absorbed by it. The fitting will usually also alter the distribution of light and send a greater or less proportion of the total direct to the area concerned. In addition, light will probably reach that area after reflection off other objects such as the walls and ceiling. The amount of such reflected light depends firstly on the amount of light which strikes these objects, again a function of the fitting, and partly on their power to redirect the light back, *i.e.* their reflection factor. Furthermore the proportion of light from any given fitting which reaches to the walls and ceiling is a function of the overall size of the room and the position of the fitting in the room. Similarly the amount of direct light which will reach the working area is a function of the mounting height of the fitting. Finally, allowance must be made for drop in illumination due to dirt on lamps and fittings, dirt or discoloration of walls and ceilings, ageing of lamps, and so on; as much as 30 per cent is a common allowance to make.

93. To sum up, it will be seen that the factors which determine illumination are:

Lamp lumens,
Efficiency of fitting,
Distribution of light from fitting,
Size of room,
Reflection factor of surroundings,
Mounting height of fitting,
Depreciation.

94. In practice, Tables giving what are known as room indices and coefficients of utilization are prepared to enable allowance to be made for these various factors. From the first of these Tables, by taking size of room and mounting height, the room index is discovered. The second Table then relates overall efficiency and light distribution of fitting to each room index with alternative figures to allow for light or dark ceilings and walls. In effect the coefficient of utilization is the percentage of initial lamp lumens which will spread over the working area of the room, without taking account of the service depreciation. To obtain, therefore, the ultimate average illumination over the area one has simply to solve an equation:

$$\text{illumination in f.c.} = \frac{(\text{lamp lumens}) \times (\text{coefficient of utilization})}{(\text{area in sq. ft.}) \times (\text{depreciation factor})}.$$

95. Tables of coefficients of utilization are sometimes published by individual fittings makers in relation to their products, but probably the Tables in most general use are those published by the Electric Lamp Manufacturers Association in their handbook *Illumination Design Data*. For multiple lamp installations where illumination is designed to be fairly uniform over a large area the Tables will give accurate results, but it must be realized that they are designed to give average illumination over an area, and therefore will not give a true picture for installations such as are commonly found in private houses consisting of one lamp only giving an illumination which is relatively high in its immediate vicinity but falls off rapidly to the sides of the room.

The depreciation, as noted above, is usually about 30 per cent, which can be inserted in the formula as a factor of 1·4.

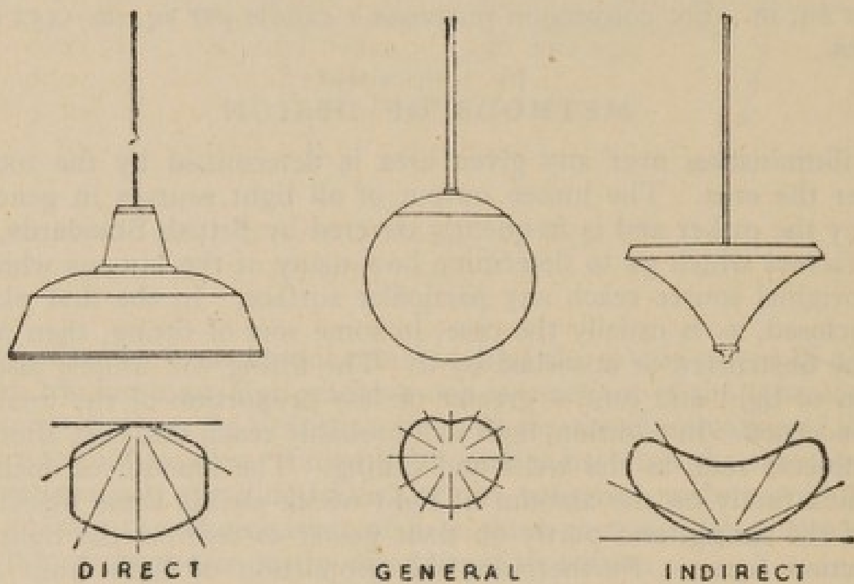


Fig. 29.

PRINCIPLES OF DESIGN

96. The above formula may appear to reduce the design of an installation to simple terms, but considerable skill and knowledge is required in the correct choice and placing of fittings.

97. In the choice of a fitting, the first factor for consideration is the nature of the light distribution required from it. Fittings are graded into classes according to their distribution; from totally indirect, from which all the light goes upward, to totally direct, from which it all goes downward. Such fittings are either described in broad terms as defined in *B.S.* 398, or their distribution is shown diagrammatically by polar curves, as described in paragraph 90. Typical shapes taken by these for direct, general, and indirect fittings are shown (Fig. 29).

When the actual type of fitting is known, the spacing and mounting height must be determined. This is usually given for the various fittings in manufacturers' catalogues or can be found in *B.S.* 398 and the E.L.M.A. handbook to which reference has been made.

98. In making the selection of a fitting, typical factors which must be considered have been mentioned in Part I of this Report. For example, totally indirect lighting may be monotonous while totally direct lighting tends to produce dark ceilings with an oppressive effect. Fittings throwing a large proportion of their light upwards will be relatively inefficient where surroundings are dark in colour, because little of the light will be reflected back. In small rooms, also, the reflection factor of walls and ceiling will generally play a bigger part than in

larger rooms. Fittings giving out most of their light at an angle just below the horizontal may prove glaring or distracting at low mounting heights; and so on. Overall efficiency, which to some extent affects the running cost, also plays its part in the selection of fittings. Certain broad variations in efficiency are inherent in fittings according to the nature of the light distribution, but if decorative effects are important some sacrifice in efficiency will often be entailed, though attractive design must not be taken to mean low efficiency as a matter of course (Plates 2, 3, and 4).

99. Although in the above paragraphs, and in subsequent sections of this Report, reference is made generally to light "fittings," we do not in any sense exclude the idea of built-in equipment, either as found at present or in new forms yet to be developed. The general principles which have been outlined will, however, apply.

100. Finally, ease of maintenance must be taken into account in both the choice and placing of the fittings, and if for some reason they have to be relatively inaccessible, extra care is required in choosing types which do not soil quickly. Far too little attention has usually been given to this factor.

ARTIFICIAL LIGHT AS A TEMPORARY OR CONTINUOUS SUPPLEMENT TO OR SUBSTITUTE FOR DAYLIGHT

101. In general, if the standards recommended in this Report as regards the provision of daylight and artificial light are adopted, every building will have reasonable natural light during the hours of daylight and reasonable artificial lighting during the hours of darkness.

While, however, artificial light can be provided with certainty, the natural light actually available at any time depends as much upon weather conditions as on the season of the year, and in so far as the natural light will normally be greatest near the window and least at the parts of the room farthest away from the window there will inevitably, on dull days or at dusk, be times in the case of deep rooms when the natural light in some parts of a room is insufficient, while that in the remainder is quite satisfactory. If the less satisfactorily lit parts of the room are occupied, care should be taken to ensure that the daylight, when it is insufficient, can be adequately supplemented by artificial light.

102. The supplementary lighting should conform to the following conditions:

1. The illumination provided over the area it is designed to light should be not less than that recommended in this Report if the area were being lit solely by artificial light.
2. The artificial light sources should be selected and placed so as to give a light which blends well with natural light and to reproduce as far as is practicable those qualities of diffusion and colour which are associated with daylight.
3. They should be so controlled that the lighting over areas likely to suffer first from lack of natural lighting can be separately brought into use.

103. The Committee have viewed examples of such supplementing of daylight with artificial light and are satisfied that with light sources now available the supplementing of daylight can be achieved so effectively that it is almost impossible to tell, until the artificial lighting is put out, that the daylight is not adequately illuminating the whole area.

104. This leads to the question as to whether in any circumstances permanent artificial light can be considered a satisfactory substitute for daylight as distinct from a supplement to it.

105. While there is no evidence before us that continuous working under artificial light adversely affects the health of the workers, we are satisfied that the admission

of daylight has a psychological value and we would strongly deprecate the entire omission of natural light from premises used for continuous working occupation such as offices, factories, etc. For this reason we consider that all new buildings should be designed to secure the daylight factors recommended in this Report unless there are cogent economic or other reasons to adopt a compromise. We cannot visualize any such reason which would justify departure from the recommendations in the case of dwelling-houses, flats, and schools, but in the case of offices in heavily built-up areas compliance with the recommendations might involve considerable restriction on building design as regards the maximum possible depth of rooms where natural lighting from one side only was available. In such cases we would consider that permanent artificial lighting at the back of the room would be justifiable provided the windows are visible to all parts of the room and the artificial lighting is suitable and sufficient.

PART III. LIGHTING IN DWELLINGS

DAYLIGHT IN DWELLINGS

106. All habitable rooms in dwellings should have adequate direct daylight during normal daylight hours over a reasonable period of the year.

STANDARDS OF DAYLIGHT ILLUMINATION IN DWELLINGS

107. We have come to the conclusion that in formulating standards of daylighting in dwellings two quantities should be specified, namely, the penetration of a selected daylight factor and the area lying within that daylight contour, a quantity which we term the "daylight area." The specification of penetration alone would no doubt ensure that in many normal cases the daylighting would be adequate in a room but it is not a safeguard in all circumstances. As has been shown earlier, it is possible with certain conditions of obstruction and certain shapes of window to have a relatively narrow beam of daylight penetrating quite deeply into a room, and while it would thereby satisfy one part of the specification, it would not provide good lighting.

108. In considering what standards of penetration and daylight area to suggest we have had the benefit of a daylight survey of over sixty flats representing a wide range of lighting conditions.

The survey has provided us with evidence of the standards of penetration and daylight area prevalent in dwellings of this kind, the opinions of the respective tenants, the opinions of the investigators themselves,[1] and the use by the tenant of artificial light to supplement the daylight. A summary of the survey forms Appendix V of our Report, and it will be seen from this that, despite the limited number of cases studied, not only is there a reasonable correlation between tenants' and investigators' opinions, and the use of artificial light, but the trends of opinion are also fairly well defined in most cases.

The survey being, so far as we are aware, the only evidence of its kind available, we have made substantial use of it in arriving at our decisions for standards, though we have supplemented it wherever necessary to take account of other factors.

109. In arriving at the suggestions for minimum standards we have assumed an average degree of obstruction by curtains. We do not consider it possible to guard against some curtaining being used by some tenants, but we believe that the provision of carefully placed curtain runners as part of the equipment of the dwelling would be helpful in this respect.

[1] The investigators received brief technical instruction to familiarize them with the elementary principles of natural lighting.

110. In all cases the standards of penetration and daylight area are assumed to read from the external face of the window wall. This obviates the need for the designer to make any adjustment for wall thickness as an allowance for walls up to 13-in. thickness has been made in deciding upon the recommendations.

111. It should be observed that reflected daylight while always desirable in rooms cannot be relied upon to increase materially the level of illumination. Its principal value is the relief of shadow, the reduction of contrast, and its effect upon the decorations.

The admixture of natural and artificial light is, in our opinion, unsuitable as a basis for standards in habitable rooms of dwellings.

WORKING KITCHENS AND SCULLERIES

112. The selection of penetration and daylight area for kitchens is largely governed by evidence from the survey that a daylight factor of 2 per cent or thereabouts is required at each of the three principal pieces of equipment: the sink, the cooker, and the work-table. The problem therefore resolves itself largely into a question of providing, to the illumination standard indicated, an area sufficient to accommodate this equipment. It follows that to obtain satisfactory results a room having only the minimum standard of lighting must have the equipment placed within that area.

TABLE 1. SUGGESTED MINIMUM DAYLIGHT STANDARDS FOR WORKING KITCHENS AND SCULLERIES

SIZE OF KITCHEN sq. ft.	DAYLIGHT FACTOR %	PENETRATION ft.	DAYLIGHT AREA sq. ft.
Up to 100	2	6	50
101–120	2	7	60

LIVING ROOMS

113. The evidence before the Committee, including that from the survey, indicates that a d.f. of 1 per cent is found desirable for the various functions carried on in the living room, *e.g.* reading and dining, or for the "well-being" of the occupants.

TABLE 2. SUGGESTED MINIMUM DAYLIGHT STANDARDS FOR LIVING ROOMS

SIZE sq. ft.	DAYLIGHT FACTOR %	PENETRATION ft.	DAYLIGHT AREA sq. ft.
Up to 150	1	8	80
151–200	1	10	100

114. BEDROOMS

TABLE 3. SUGGESTED MINIMUM DAYLIGHT STANDARDS FOR BEDROOMS

SIZE sq. ft.	DAYLIGHT FACTOR %	PENETRATION ft.	DAYLIGHT AREA sq. ft.
Up to 110	0·5	8	60
111–150	0·5	10	90
151–200	0·5	12	120

DUAL PURPOSE ROOMS

115. Rooms intended for more than one main function, *e.g.* kitchen-dining rooms and bed-sitting rooms, should satisfy all the appropriate standards. For instance, a kitchen-dining room of 120 sq. ft. should have a daylight factor of 2 per cent penetrating to a depth of 7 ft. and covering an area of 60 sq. ft. to satisfy the kitchen standard, and a daylight factor of 1 per cent penetrating 8 ft. and covering an area of 80 sq. ft. to satisfy the living-room standard of this size. Similarly a bed-sitting room should satisfy the combined standards for a bedroom and a living room.

METHODS OF DECIDING WINDOW SIZES UNDER NORMAL CONDITIONS

116. It follows from the discussion of obstruction and town planning that certain guiding factors should influence the density of development and the type of site layout for houses and flats.

In the design of individual buildings it is important to be able to decide quickly and easily what arrangement of windows will give the required results, and we believe that for most normal cases it should be possible to do this by using Tables of the first or second types described in paragraphs 39 and 40 of this Report.

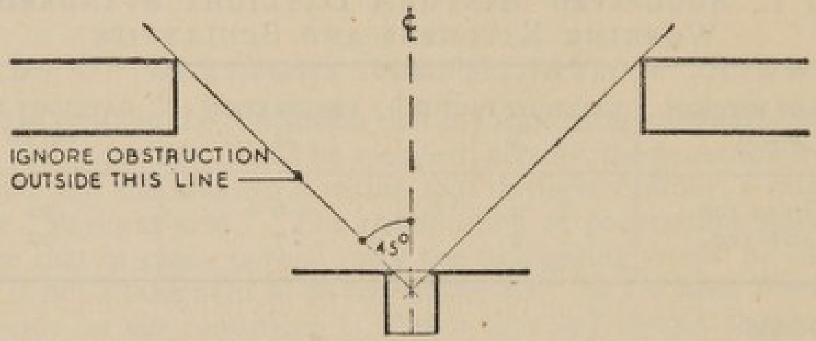


Fig. 30. DIAGRAM PLAN OF ROOM IN RELATION TO OBSTRUCTIONS

The procedure would be as follows:

a. Knowing the size of room and its purpose, decide upon the penetration and daylight area required. (Either the minimum values given in paragraphs 112 to 115, or greater values if desired.)

b. Decide upon the average angle of external obstructions. For this purpose obstructions falling outside a horizontal angle of 45° to a line normal to the centre of the window may be ignored (Fig. 30).

The average vertical angle of obstructions falling within the 90° horizontal angle may be simply obtained when the range does not vary by more than 20°. Where the range is more than 20° a special analysis may have to be made, though a little experience should enable many of these cases also to be estimated effectively.

We assume that a description of how to average the height of obstructions will be published with the N.P.L. Tables.

c. From the Tables choose a window which, with an average angle of obstruction similar to that obtaining, gives the required penetration and daylight area.

117. In order to obtain the recommended standards without unnecessarily large windows it is desirable to keep the window head as high as possible, and we recommend for dwellings a minimum height of 7 ft., but would advise 7 ft. 6 in. as being more desirable for all living rooms and kitchens. The Committee was given

facilities for trials at the National Physical Laboratory which indicated that such heights also provide illumination of a better quality than from lower windows, the improvements being due to the steeper angle of the light.

METHODS OF DECIDING WINDOW SIZES UNDER SPECIAL CONDITIONS

BAY WINDOWS

118. As explained in paragraph 27, a bay window provides high illumination within the area of the bay but reduces illumination elsewhere in the room. In order to maintain a reasonable daylight area in the body of the room it is necessary to make the opening into the bay rather larger than the equivalent normal window would have to be. We suggest that the size of the opening be determined as if it were for an ordinary window but with an increased standard of penetration and daylight area.

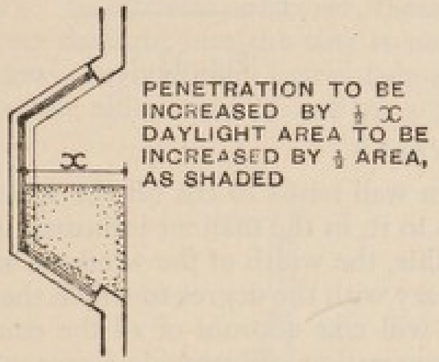


Fig. 31.

We have made a brief examination of the problem to find a suitable rule by which this can be done, taking into account the depth and useful area of the proposed bay. We suggest that the normal penetration requirement be increased by half the proposed depth of the bay, and the daylight area requirement be increased similarly by half the area of the bay (Fig. 31).

BALCONIES

119. A balcony which overshadows a window reduces the penetration of light into the room. The extent of the reduction depends on the depth, length, and height above working plane of the balcony. To take all factors into account would require a complex rule, but the main points can be covered by the following simple

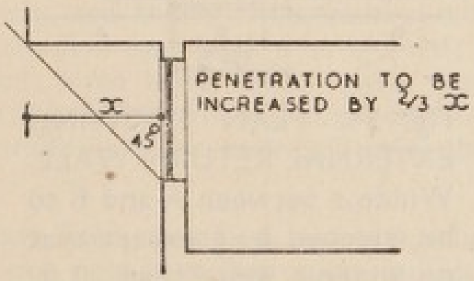


Fig. 32.

method. The window size should be increased by an amount which would normally give the stated standard of penetration for the room plus two-thirds the depth of the balcony, and with the proviso that the balcony should not extend beyond a line at an angle of elevation of 45° from the sill, as shown in Fig. 32. This assumes that the balconies of flats and houses will be at the normal ceiling height; should they be higher some relaxation of the rule might be permitted.

DORMER WINDOWS

120. These are very similar to bay windows except that the sides are not open. We suggest that the standards for penetration and daylight area should be increased respectively by two-thirds the depth and horizontal plan area of the dormer. For this purpose the depth would be the distance from the window head back to the line of the wall of the room, or to the line of the roof, whichever is greater (Fig. 33).

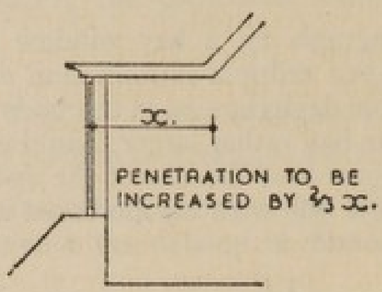


Fig. 33.

EXTERNAL RETURN WALLS

121. An external return wall tends to cut off the spread of illumination in those rooms which are nearest to it, in the manner indicated in paragraph 33. It is clear that in order to correct this, the width of the windows affected should be increased to an extent which will vary with the degree to which the room is shadowed. There is no simple rule which will take account of all the complex factors involved, but we think the following suggestion will provide a reasonable solution: all windows lying within a horizontal angle of 45° from the outer edge of a return wall should be increased in width 25 per cent (Fig. 34), except that windows more than 50 ft. from any return wall need not be corrected regardless of the length of the return wall.

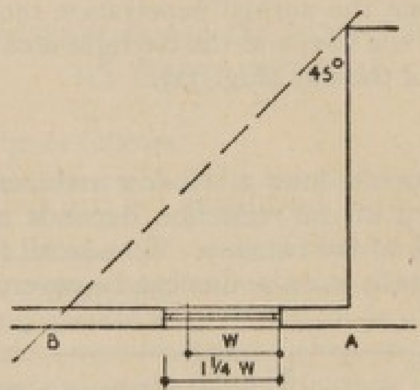


Fig. 34. PLAN SHOWING EXTERNAL RETURN WALL. Window between A and B to be widened by ¼ except that no window more than 50 ft. from A need be increased.

(We have in mind here that return walls of great length will not normally have heights of more than 10 storeys in flatted development in this country.) All windows would be considered unaffected one storey down from the top of the return wall, and windows two storeys down should require only half the correction applied to the remainder.

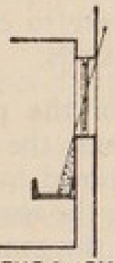
THE POSITION OF WINDOWS IN RELATION TO INTERNAL WALLS

122. From a study of paragraph 23 it is obvious that in the case of a window placed immediately against an internal partition some of the daylight contour would be cut by the partition. It is felt that this is unlikely to be of sufficient moment to necessitate any need for alteration of standards, although it does suggest that study of the placing of windows in relation to the room is advisable so as to ensure the daylight falling in the part of the room where it will be most useful.

123. Where the area of window required for a given standard is subdivided into two or more windows, at least one of these should permit daylight penetration to a depth equal to three-quarters of the depth required for the standard, unless it can be shown that the daylighting is otherwise adequate.

KITCHEN WINDOWS

124. In the case of most windows the sill height has comparatively little effect on the lighting within a room. In kitchens, however, there is one point to watch. Adequate penetration of direct daylight into the sink is necessary. If the sink is placed directly under a window a high sill will cast a deep shadow across the sink. It is therefore suggested that the sill should be not more than about 6 in. above the top of the sink (Fig. 35).



SECTION THROUGH WINDOW & SINK,

Fig. 35.

RELATION OF STANDARDS TO DENSITY OF DEVELOPMENT

125. We have considered the proposed standards in relation to the arrangement of buildings, the density of development, and the size and shape of windows. We have found that they are practicable.

126. The density of normal suburban housing, measured as a floor space index, is of the order of 0·3 to 0·5, and angles of obstruction will not generally exceed 15°. This degree of obstruction may largely be ignored, although when houses are inequitably distributed, some being much nearer together than others, individual cases of obstruction will occur and need attention. Windows on the ends of houses will generally be more restricted in outlook than those on the front or back.

127. Flatted schemes have been examined, and it has been found that typical recent developments in open sites have floor space indices from ·75 to 1·25, the lower figures being representative of Scottish practice rather than English, and angles of obstruction of 18°–20° are common. In cities there is a tendency to increase the density of flatted developments, and some modern ones seen in London have indices as high as 1·7 or 2·0. Earlier schemes in London had indices up to nearly 3.

128. With densities of the order of 1 or 1·2 it was found that the daylighting in general was not bad, and that the necessary improvements could have been

made by increasing the size of the windows on the lower floors, or by avoiding balconies in certain places, and so on. Since in general these buildings were four or five storeys high, often in great length and often parallel to one another, their daylighting could have been improved by more height and greater spacings. In these cases the density is so low that a serrated sky-line is not entirely necessary for illumination on the working plane. At the same time, it would improve the quality of the illumination to have the serrations because the walls of the rooms are made brighter, and we therefore recommend that, even on development of this density, the authoritative planning bodies should encourage the application of the principles discussed in Part II, and in particular the use of shorter buildings, arranged to permit better views of the sky from all habitable rooms. Long return walls are not generally desirable, nor open courts.

129. It is worth noting here that in flatted schemes in Sweden something of the same kind is encouraged for the purpose of improving the vista. It is apparently found to relieve the sense of enclosure which otherwise may be experienced in looking out upon endless parallel obstructions, and also improves the daylighting.

130. Flatted schemes of densities higher than 1·5 in London were found to offer poor daylighting, or even, in some cases, none at all. The fault lay partly in the design of individual buildings, but it was found that the heights and spacing of buildings were in any case inadequate for these densities. In cases of this kind it will obviously be necessary to consider the improved types of layout in order to meet the proposed standards.

131. To illustrate the effect of the proposed standards on window sizes at different densities of development, the following table has been prepared. In these examples glass area is assumed to be 75 per cent of the window opening, and the window head 5 ft. above the working plane.

Type 1 development refers to the generally horizontal form of obstruction, and type 2 to the generally vertical or broken pattern of building.

TABLE 4. TABLE RELATING WINDOW SIZES TO DENSITIES OF DEVELOPMENT

	FLOOR SPACE INDEX	TYPE OF DEVELOPMENT	WIDTH OF GROUND FLOOR WINDOW
Kitchens	1·0	Type 1 or Type 2	5′ 4″
	1·5	Type 1	7′ 6″
	1·5	" 2	6′ 0″
	2·0	" 1	Impossible [1]
	2·0	" 2	7′ 0″
Living Rooms 151–200 sq. ft.	1·0	Type 1	9′ 3″
	1·0	" 2	6′ 0″
	1·5	" 1	Impossible [1]
	1·5	" 2	8′ 3″
	2·0	" 1	Impossible [1]
	2·0	" 2	12′ 0″
Bedrooms 111–150 sq. ft.	1·0	Type 1 or Type 2	3′ 6″
	1·5	Type 1	Impossible [1]
	1·5	" 2	4′ 6″
	2·0	" 1	Impossible [1]
	2·0	" 2	6′ 8″

[1] Ultimate limit of penetration is below the proposed standard.

132. The use of this Table can be effectively illustrated by showing what sizes of windows are required at different floor levels in blocks of flats where the general development is up to a density represented by a floor space index of 2. Levels intermediate between the top and bottom storeys are then representative of intermediate densities as shown.

Fig. 36 is a commentary on modern practice in fenestration, which largely omits the graduation of window size from top to bottom of a building.

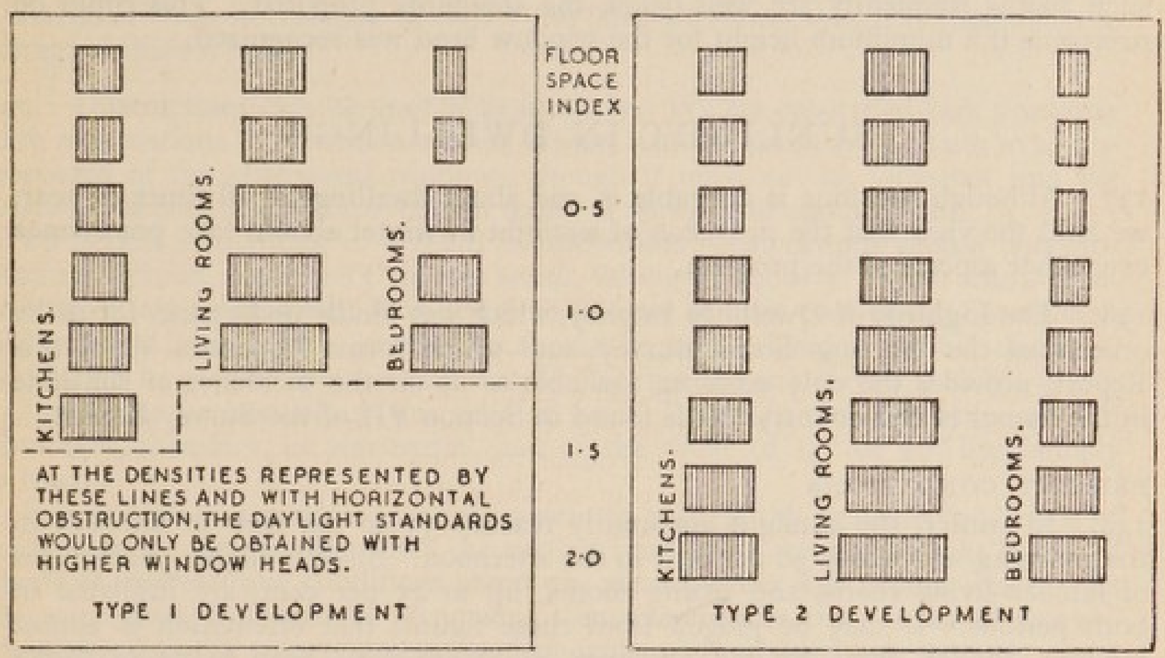


Fig. 36. DIAGRAM FAÇADES SHOWING GRADUATED WINDOW SIZES REQUIRED TO GIVE STANDARDS AT VARIOUS DENSITIES FOR THE TYPES OF DEVELOPMENT

133. Table 4 has a certain importance in that it not only shows the actual window sizes involved, and the advantages of the vertical developments in reducing window sizes necessary, but also the limits of density which are practicable. It will be seen, for instance, that floor space indices of 1·5 are quite acceptable in lighting; that is a higher value than is now used. Even an index of 2 is not ruled out, though it would mean a big window in the living room on the lower floors; it would be a small price to pay for the denser developments if these are considered desirable in other respects.

DETAILS OF CONSTRUCTION

134. The rule suggested for dealing with the case where a window is shadowed by a balcony—paragraph 119—would have the effect, so far as we can judge, of greatly reducing the use of approach balconies over such rooms as kitchens and living rooms on the lower floors of flatted schemes several storeys high. The use of balconies in these circumstances, on the whole, appears to be incompatible with the requirements of daylighting.

135. We have considered the splaying of window reveals, externally and internally. We have noted that if the splay is external, it may add to the apparent height of the window and permit a better view of the sky. On the other hand, internal splays ease the transition from the relative darkness of surrounding wall surfaces to the brightness visible outdoors. In addition they permit a good

spread of light. The result either way is a nett gain, and we, therefore, recommend that one or other of the alternatives be used where windows are narrow or in thick walls, and that the principle be commended generally.

136. We have observed that, in some housing, the height of window head in some rooms is lowered to correspond to the head of a door into the garden. The transome is frequently not used. The result is that the daylighting of these rooms is unnecessarily poor, and despite the reduced floor space indices for housing, such rooms frequently are well below the standards proposed. This could be overcome if a mimimum height for the window head was recognized.

SUNLIGHT IN DWELLINGS

137. Although sunshine is desirable in and about dwellings at all times of year, we hold the view that the provision of sunlight in winter should take precedence over other aspects of the problem.

138. The Lighting of Dwellings Inquiry, which was kindly undertaken for us by officers of the Wartime Social Survey, and which forms Appendix VI of this Report, provides the only evidence available to us on the incidence of sunshine in the homes of this country. It is found in Section VII of the Survey Report.

PRESENT CONDITIONS

139. In winter, the sunlight apparently reaches 35–40 per cent of kitchens in the morning and about 30 per cent in the afternoon. Slightly higher percentages of kitchen-living rooms and sitting rooms, up to 45 per cent, are insolated in both periods. It may be judged from these figures that orientation is almost random, though some limited attempts appear to have been made to direct kitchens eastward and living rooms southward.

140. No material differences were observed between flats and houses, but for both there has been a general improvement in insolation since the last war. This may be attributed largely to a reduction in the density of housing developments, though there is a more marked improvement in the sitting room than elsewhere, which indicates that designers are giving increased attention to the problem.

PREFERENCES OF THE PEOPLE

141. The opinions of householders were divided on the question of sunlight in the morning in winter. Twenty-nine per cent said they would like it in the kitchen, 49 per cent in the kitchen-living room, and 13 per cent in the sitting room.

Opinions regarding sunlight in the afternoon in winter are more conclusive; only 5 per cent were interested in the kitchen as against 47 per cent in the sitting room and 45 per cent in the kitchen-living room. This is interpreted by the Wartime Social Survey as meaning that 87 per cent of the people want the sunlight in the sitting room in the afternoon, or approximately 9 out of every 10.

142. We therefore conclude and recommend that designers should make provision for sunlight in sitting rooms or kitchen-living rooms in the afternoon in winter. Morning sunlight in the kitchen may be regarded as a secondary but not unimportant consideration for working-class housing, though the position is somewhat different with higher income groups.

SUNLIGHTING OF INTERIORS

143. If the living room is to receive sunshine in the afternoon two conditions of design must be satisfied:

a. one window of the living room must be correctly oriented;

b. obstructions to the afternoon sun must be restricted.

144. It is observed in paragraph 67 that the extreme limits of orientation for windows to receive winter sun at some time of day are from about east-north-east to west-north-west. Since living rooms are to receive sunlight in the afternoon primarily, these limits may be halved, ranging then from due south to west-north-west.

In fact, some sun in the period immediately after midday would penetrate windows orientated as far eastward as south-east, but since the meaning of "afternoon" sun in this case is clearly the later afternoon sun, it is reasonable to disregard this extension.

145. Obstructions may be dealt with similarly. We are concerned here primarily with obstructions to afternoon sun in winter, namely, those lying south to south-westward of the obstructed windows, though it must not be forgotten that the westward aspect is also important in terms of spring and summer sun.

To permit sunlighting of a room in mid-winter, obstructions should not subtend so high an angle as 15° in the south, falling to about 5° in the south-west, and there is no doubt that it is desirable to have at least part of the obstruction within these limits. How much of it should be so restricted is another question, which will in part be answered by mentioning that the sun travels through nearly 15° per hour horizontally at this time of year. Breaks in the obstruction should obviously, therefore, be substantial, and of the order of 15° or 20° horizontally at least.

If it should be considered unduly severe to suggest the extreme conditions of mid-winter as the criterion, then the vertical limits of obstruction might be raised about 5°, representing conditions about one month either side of mid-winter. At the same time, it should be recognized that this reduces the "factor of safety" which is otherwise present to ensure reasonable winter sunshine.

It should not be thought that when a gap of the size indicated here has been provided it will be safe to carry the remainder of the obstruction to indefinite heights. The sun might never shine just in the right place in winter, and we think therefore that it would be wise to keep obstructions in all the south to west region generally below about 20°.

146. In areas of suburban housing, where for the most part obstructions do not exceed 15°, the conditions could be satisfied by orientation of one window in the main living room of each house, and it might be considered whether this could be made a requirement; it ought not to be unreasonably restrictive or difficult to administer.

147. In flatted schemes of higher density more care would be needed in dealing with obstructions, but at the same time skilled designers are usually employed, and with suitable instruction and practice ought to be able to manage the problem. It is clearly a matter of some interest to the occupier, and since it need not add to the national demand on manpower or materials, but only on ingenuity, it should be given sympathetic consideration.

148. In summer, the exclusion of heat from bedrooms should not be neglected; bedrooms facing south-west to north-west are most likely to be affected, and permanent shelter by a hood of some kind should be considered.

THE SUNLIGHTING OF THE GROUND AROUND DWELLINGS

149. The sunlighting of the ground around houses has a certain direct importance to the householder, for gardens which are heavily shadowed in winter are difficult to maintain and less productive. Winter shadowing to the north of a single house is less serious that it is behind a pair of houses or a terrace, and on these latter cases the main axis of the blocks of buildings should not lie east and west, when the maximum of shadowing is caused.

150. The sunlighting of the ground around flats is perhaps less important in the sense that it is not cultivated so intensively, but is nevertheless desirable so far as possible.

THE SUNLIGHTING OF STREETS

151. Street layouts have been discussed previously, and little need be added here. When streets are aligned east and west, buildings parallel to the street line cause a maximum of winter shadow; alternative relationships between buildings and streets should therefore be attempted. If culs-de-sac are employed, these would usually lie at right angles to the traffic thoroughfare, or north and south, so that their orientation and the buildings on them should be satisfactory.

ARTIFICIAL LIGHT IN DWELLINGS

152. We consider that all dwellings should be equipped for artificial lighting at the time of erection and that such equipment should be adequate to provide at least the minimum standards suggested in this Report.

RECOMMENDED STANDARDS OF ARTIFICIAL ILLUMINATION IN DWELLINGS

153. The following is an abstract of recommendations for illumination values as given in the current Illuminating Engineering Society Code:

		FOOT-CANDLES
Bathroom—	General	6–10
	Mirrors	Special Lighting
Bedrooms—	General	4–6
	Beds and mirrors	Special Lighting
Kitchens—	Cookers, sinks, and tables	6–10
Reading—	Casual	6–10
	Sustained and homework	10–15
Sewing		15–25
Stairs		2–4

In so far as we have thought it necessary to make recommendations for minimum standards for small dwellings we have based these on values obtained largely by experiment. These values, although lower than the well-established Illuminating Engineering Society Code, appear to us to be reasonable as recommendations for minimum standards.

WORKING KITCHENS OR SCULLERIES

154. *Number and Position of Outlets.* We consider that lighting points should be so arranged that the lights give adequate illumination to the sink, cooker, and table without heavy shadowing from the worker. Usually this will mean at least two light sources placed conveniently in relation to the sink, cooker, and table. Separate switching for these lights is desirable.[1]

155. *Standardization of Working Kitchen or Scullery Light Fittings.* We recommend that a British Standard (also referred to in paragraph 209) should be prepared covering the following points for working kitchen or scullery light fittings:

a. Overall efficiency should be specified. We believe a minimum of 70 per cent would be reasonable. In the case of superheated gas burners this 70 per cent should be taken in relation to the lumens output of the source operating at the ambient temperature enforced by the fitting.

[1] Switching is meant to imply any type of control either for gas or electricity.

b. Of this light emitted from the fitting at least ¼ should be in the upper hemisphere and at least ½ in the lower.

c. Brightness when measured over any reasonable area and at any angle of view between the horizontal and 60° from the downward vertical should not exceed 10 candles per sq. in.[1]

d. The fittings should be marked for the sizes of lamps or mantles for which they are intended.

e. Interchangeability of shades and standardization of the fixing of the fittings is desirable whenever possible.

f. Simple detachment of the glass or shade is desirable for the purpose of cleaning, re-mantling, or re-lamping.

g. Enclosed fittings, if used, should be dust-tight as far as is consistent with the efficient working of the source.

h. A few good fittings which would meet the requirements should be illustrated in outline.

156. *Recommendations for Sizes of Lamps or Mantles in Working Kitchens or Sculleries.* Taking into account the above recommendations and assuming a usual utilization coefficient of 0·4 and a depreciation factor of 1·4, we are of the opinion that the following should give reasonably adequate lighting if the fittings are carefully placed in relation to sink, cooker, and table. Because the lighting is most important at these three work-places the requirements do not vary greatly with moderate differences in room size, and it will be noticed that our recommendations for total power of light sources in kitchens do not, in fact, vary greatly in this respect.

<table>
<tr><td>Rooms up to 80 sq. ft. 100 watts, or three B.S. 1 (or one B.S. 4 plus one B.S. 1 mantle)</td><td rowspan="2">where 2 fittings are used</td></tr>
<tr><td>Rooms of 80–120 sq. ft. 115 watts, or four B.S. 1 (or one B.S. 4 plus one B.S. 1 mantle)</td></tr>
</table>

Assuming the use of British Standard lamps or mantles, calculations and experiments have shown that illumination values of the order of 4 foot-candles would be realized under these conditions. We feel, however, that higher wattages or larger mantles resulting in up to 50 per cent increase in light output are desirable whenever possible. We also consider that the decorations of the rooms should be as light as possible, and we suggest that a figure of 70 per cent should be aimed at for the reflection factor of ceilings and the upper half of walls.

LIVING ROOMS

157. *Illumination Values.* The Illuminating Engineering Society Code recommends the following values: 6–10 f.c. for casual reading, 10–15 f.c. for sustained reading, 15–25 f.c. for sewing.

158. We consider that the illumination from the general light source should be sufficient to provide at least 3 f.c. over half the area of the room in order that a reasonable minimum illumination should be obtained when, for any reason, supplementary lighting is not used. We consider that the I.E.S. Code values for special tasks are reasonable, and we think these should be obtained by adequate provision of additional plug points for local lighting.

159. *Number and Position of Light Points.* We recommend the provision of one fixed fitting so placed that the conditions in paragraph 158 can be met. Usually the position for this will be in the centre of the ceiling, although an exception to this may be desirable in cases where a fireplace is at one end of a long room, when

[1] This is not intended to prohibit the use of fittings such as the prismatic glass type which may have small areas operating at brightnesses exceeding 10 candles per sq. in.

either two fixed lighting points should be provided or a single one placed to give the best light around the fireplace area.

160. We also recommend the provision of three additional plug points in order to allow flexibility in the placing of local lighting. It could usually be assumed that one of these would be available for purposes other than lighting. Any additional requirements for heating or other purposes should be met by further points.

161. *Standardization of Fixed Light Fittings for Living Rooms.* In the case of living rooms of dwellings built either by private enterprise or by public authorities in which fittings should be installed and included in the cost of the dwelling, it is desirable to ensure that adequate illumination is provided at reasonable running cost, but within these provisos, to allow the greatest latitude possible for individual taste and standards of income. The latter requirement makes it difficult to deal with the matter by detailed British Standards for fittings without either having a very wide range of specifications or unduly limiting the scope of variation in design. It is suggested that the problem could be satisfactorily solved by dealing direct with the main requirement, namely, adequate illumination at reasonable cost, and this is attempted in the following paragraphs.

162. Illumination is a function of lamp lumens, coefficient of utilization and service depreciation. Coefficient of utilization takes into account overall loss of light in the fitting, the size, shape, and decoration of the room, and the nature of the light distribution from the fitting.

For the class of room under consideration the influence of the size, shape, and decoration has been taken as constant.

The depreciation factor can also be considered as constant, and a figure of 1·4 has been taken.

163. It is further suggested that to ensure reasonably economic performance a minimum overall efficiency of fittings should be laid down. A figure of 60 per cent is suggested as a minimum, but as the average of fittings would be materially higher the recommendations which follow have been based on a figure of 65 per cent.

164. This leaves as the only variable affecting the coefficient of utilization the nature of the light distribution.

It is suggested that fittings of the type visualized for the general lighting of the room could be divided broadly into three categories, and these have been used for the purpose of our calculations:

A. Mainly direct—at least 70 per cent of total light output of the fitting to lower hemisphere.
B. General, giving approximately the same amount of light upwards and downwards.
C. Mainly indirect—at least 70 per cent of total light output of the fitting to upper hemisphere.

165. In the living room personal preference should be the main thing governing the choice of the type of fitting, but some control over "glare" is desirable in the best interests of the user. We feel that the best method would be to include in the British Standard a maximum brightness clause. Fittings conforming to this requirement would obviate excessive glare while leaving reasonable freedom in design. At the same time it is desirable to encourage the use of fittings of a more restrictive type, *i.e.* with a considerably lower brightness, and as a guide to what we consider would be good practice for this purpose we suggest that a specification of a "no glare fitting" should be included in the British Standard.

166. We therefore recommend that a British Standard should cover the following points for living-room fittings:

a. Overall efficiency. We suggest a minimum of 60 per cent.
b. Definition of types of fittings to be classified as: A. Mainly Direct, B. General, C. Mainly Indirect.
c. Brightness when measured over any reasonable area at any angle of view between the horizontal and 60° from the downward vertical should not exceed 10 candles per sq. in.[1] To conform with paragraph 165 the specification should also include the requirement for no glare fittings.
d. The fittings should be marked for the size of lamp or mantle for which they are intended.
e. Interchangeability of shades and some standardization of the fixing of the fittings is desirable whenever possible.
f. Simple detachment of the glass or shade is desirable for the purpose of re-mantling or re-lamping.
g. A few good fittings which would meet the requirements should be illustrated in outline.
h. It is impracticable to suggest control of the fittings to be attached to plug points, but we suggest that the British Standard for study lamps might be extended to cover other types of portable lamps. In this way it might be possible to influence the design of such fittings.

167. *Recommendations for Sizes of Lamps and Mantles in the Fixed Light for Living Rooms.* We consider that it is important to provide some simple method of deciding the sizes of lamps or mantles necessary to give the general illumination values recommended in paragraph 158. We believe the chart given in Fig. 37 provides such a method. Before preparing this chart we considered specifying in tabular form a definite size of lamps and mantles suitable for three sizes of room, but we concluded that this method was not sufficiently elastic in allowing for a range of room sizes.

We therefore recommend that the British Standards referred to in paragraph 166 should include some such chart as Fig. 37 as a recommendation for the sizes of lamps or mantles to be used with the British Standard fittings.

168. For living rooms of 120, 150, and 200 sq. ft. our recommendations would require the following wattages in the main fitting to be used for electric lighting:

TABLE 5. WATTAGES RECOMMENDED FOR MAIN FITTING IN LIVING ROOMS

ROOM SIZE	FITTING		
	Type A (Direct)	Type B (General)	Type C (Indirect)
120	100	100	200
150	150	150	200
200	150	200	300

[1] This is not intended to prohibit the use of fittings such as the prismatic glass type which may have small areas operating at brightnesses exceeding 10 candles per sq. in.

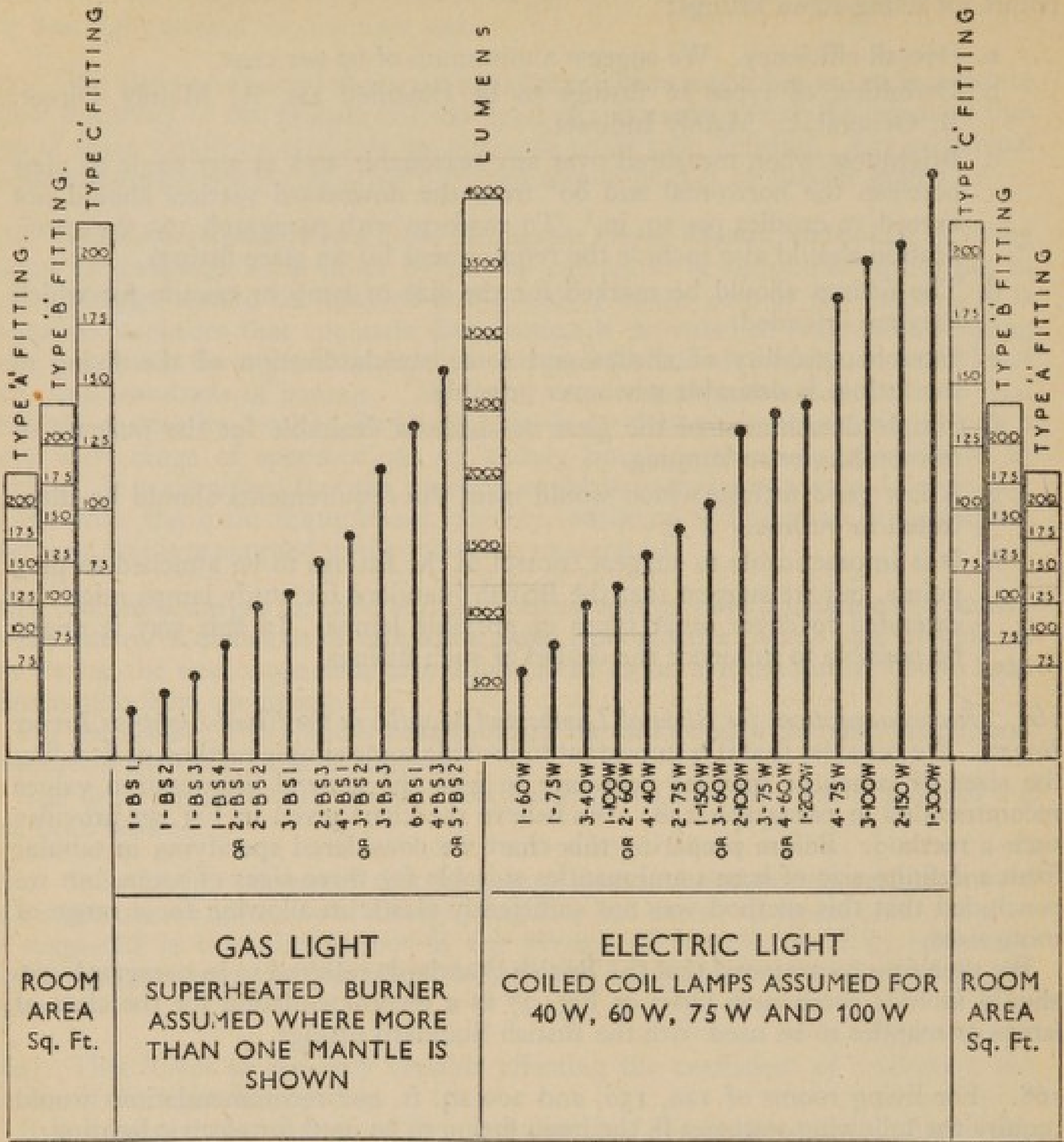


CHART FOR DETERMINING SIZE OF LAMP OR MANTLE IN FIXED FITTINGS FOR LIVING ROOM LIGHTING

INSTRUCTIONS FOR USE

1. Decide on Type of Fitting to be used. Refer this to Scales on each side of Chart.
2. Determine Area of Room and find appropriate point on Scale on either side of Chart.
3. Lay a ruler across from points determined at 2 above and the intersection with Lamp or Mantle Columns in the centre gives the minimum size of Lamps or Mantle or combinations of these to give satisfactory Lighting.

Fig. 37.

169. In the case of gas lighting we believe that our recommendations would require the sizes of mantles given in Table 6:

TABLE 6. MANTLE SIZES RECOMMENDED FOR MAIN FITTING IN LIVING ROOMS

ROOM SIZE	TYPE OF FITTING	
	A	B
120 sq. ft.	2 *B.S.* 2	2 *B.S.* 3
150 sq. ft.	2 *B.S.* 3	4 *B.S.* 1 or 3 *B.S.* 2
200 sq. ft.	4 *B.S.* 1 or 3 *B.S.* 2	6 *B.S.* 1

Note: Type C fittings are not generally used for gas lighting.

DUAL PURPOSE ROOMS

170. The lighting of these requires to be adjusted to the special requirements of each case depending upon the type of use which is likely to be made of the room and the size and shape of the room. We assume that such rooms may vary from those intended simply for dining use in addition to cooking, etc. to those used as general living rooms. The standards set out for both kitchens and living rooms should be applied in so far as they are appropriate.

171. In rooms intended only for dining in addition to normal kitchen use the standards suggested for kitchens of 120 sq. ft. should be adequate. These standards should also provide adequate lighting for casual reading within the area where this might occasionally be required.

172. In rooms intended for general use as living rooms as well as normal kitchen use, we consider that the recommendations for living rooms should be followed with the provision of the additional second ceiling or wall fitting for lighting of the sink and cooker.

BATHROOMS

173. *Illumination Values. Number, Position, and Size of Lights.* We consider that for bathrooms with light decorations reasonable lighting should be obtainable with a 60 watt lamp or *B.S.* 3 mantle.

It is usually an advantage if the light is placed in relation to the mirror, preferably in the form of a bracket or ceiling light above the mirror.

174. *Standardization of Bathroom Fittings.* For bathroom light fittings we recommend that the British Standards referred to in paragraph 209 should cover the points given in paragraph 155 (a) to (h), but in addition they should be all insulated fittings and should not be suspended on flexibles.

BEDROOMS

175. *Illumination Values.* We consider that the essentials in bedroom lighting are a light at the bed-head, good lighting for the dressing table, and sufficient light elsewhere for reasonable convenience, including seeing into cupboards. In some cases it may, in addition, be very desirable to have good lighting at a table where homework or similar tasks can be done. In addition, good lighting needs to be provided for washing when a basin is included as part of the equipment of a bedroom.

176. *Number and Position of Lighting Points.* The position of fixed fittings should be arranged as far as possible in relation to the positions of furniture. Where the position of furniture cannot be determined in advance it will be necessary to provide adequate outlets to meet the requirements of varying arrangements.

177. We therefore suggest that the following outlets should be provided:

a. Where furniture is fixed:
   - 1 bed-head light in fixed position.
   - 1 dressing-table light. Fixed in relation to the dressing table but also to give reasonable general lighting of the room.
   - 1 plug point in addition.

b. Where position of furniture cannot be foretold:
   - 1 general light from the ceiling.
   - 2 plug points in addition.

In both cases it should be possible to control one light from the door and one light from the bed.

178. The above recommendations are considered as minimum requirements for most normal rooms. In some cases the design of the room may necessitate additional outlets.

179. *Size of Lamps or Mantles and Type of Fittings in Bedrooms.* Classes A, B, and C fittings as described for living rooms are applicable as fittings for the general or dressing-table light in bedrooms, and we recommend that the British Standard referred to in paragraph 209 should be prepared accordingly.

180. We consider that personal choice should be the chief factor controlling fittings, and size of lamps or mantles for local lights.

181. The lighting conditions required in bedrooms are different from those of living rooms, and we do not suggest that the chart shown in Fig. 37 should be used in deciding the size of lamp or mantle for bedrooms. We recommend the following lamp or mantle sizes for the general or dressing-table light fitting:

TABLE 7. RECOMMENDED LAMP AND MANTLE SIZES FOR BEDROOMS

FITTING	BEDROOMS UP TO 120 SQ. FT. AREA	BEDROOMS OVER 120 SQ. FT. AREA
Types A and B	60 watts or 1 *B.S.* 3	100 watts or 3 *B.S.* 1
Type C	100 watts [1]	— —

[1] *Note:* Type C fittings are not normally used with gas lighting.

W.C. LIGHTING

182. Where w.c.s are in separate rooms the light should be placed over the w.c. fitment. A 25-watt lamp or *B.S.* 1 mantle should be adequate.

A fitting to the lamp or burner is not considered essential, but if provided it should be easy to clean and to re-lamp or re-mantle. Where a lamp is not provided with a fitting it is preferable to have it on a batten holder on the ceiling and not suspended on a flexible.

STAIRS AND PASSAGES WITHIN A HOUSE OR FLAT

183. The arrangement of the lighting for stairs is quite as important as the provision of adequate light. The aim should be to provide a good contrast between the edge of each tread and the surface of the tread immediately below it, and to do this without causing glare to anyone ascending or descending.

184. Since it is seldom that anyone ascending a stairway lifts his gaze much above the horizontal, the aim just stated can be achieved in the case of a straight continuous stairway by placing a lamp at or near the head of the stairs so that each tread casts on the tread below a marked shadow covering between one-quarter and three-quarters of the width of that tread. The placing of this lamp off centre of the flight of steps may reduce the tendency to self shadowing by a person descending the stair. Using this rule it is a simple matter, on a sectional elevation of the stairway, to find the region within which the light source should be situated.

185. Where the stairway is not straight the best position for the lamp may be less easy to determine, but the result to be aimed at is the same.

186. Where a lamp is provided exclusively or primarily for the lighting of the stairway, a simple fitting of either type A or B, with a 40-watt lamp or *B.S.* 1 mantle should generally be adequate. (Since shadows are required a type C fitting should not be used.) Sometimes, however, it may be possible and convenient to use a single lamp for lighting both the stairway and a landing. In this case the position of the lamp should be governed principally by the stairway requirements, and a larger lamp may be needed in order to provide adequate illumination of the landing.

187. In order to avoid glare to anyone descending the stairway, any fitting used for lighting the hall or passage at the bottom of the stairway should, if possible, be so placed that it is out of the normal field of view of anyone using the stairway for descent. If this is impossible or undesirable, having regard to proper lighting of the hall or passage, the fitting should have a brightness not exceeding 10 candles per sq. in. in any direction within the field of view of anyone descending the stairway, and it should be so placed that it is as far removed as convenient from normal direction of view of anyone looking at the treads of the stairs, in the act of descending.

188. Any lamp used for lighting a stairway should be controllable from two positions, one near the top and the other near the bottom of the stairway.

189. In some plans it may be found impossible to light the hall, landing, and passages adequately from the light serving the stairs. Where this is the case additional lights will be required. They should be located with special reference to the lighting of cupboards as well as for lighting of the passage, hall, or landing.

COMMUNAL STAIRS, ACCESS CORRIDORS, AND BALCONIES

190. *Stairs.* The principles outlined in paragraphs 183 to 187 above apply also to communal stairs. Positions needing special consideration are:

a. Steps at, or just within, an entrance.
b. The foot of the first flight, where higher illumination is required.
c. Steps in unusual places.
d. Winding and narrowing steps.
e. Doors, especially name-plates and keyholes.

The minimum illumination on any tread should not be less than 0·2 f.c.

A permanently light-toned material should be used at the edge of every step to enhance its contrast with the tread below. In old buildings where it is impossible to provide this the minimum illumination on any tread should not be less than 0·5 f.c. (While it is impossible to lay down precise methods of lighting stairs, the above standards would be obtained most easily with lights at fairly frequent intervals.)

The surface of ceilings and upper parts of walls above stairs should be kept as light in tone as possible.

191. *Access Corridors and Balconies.* The minimum illumination at ground level should not be less than 0·2 f.c.

The ceilings and upper parts of walls should be kept as light in tone as possible.

Arrangements should be made to ensure the satisfactory maintenance of lighting to communal stairs, access corridors, and balconies to the above standards.

CUPBOARDS

192. In a number of the above sections the need for reasonable lighting of cupboards has been mentioned. For the sake of economy it is desirable to light cupboards from lights used for general lighting, but where adequate illumination is not possible special lighting should be provided. It is considered that it is particularly desirable to ensure adequate lighting to fuel stores, larders, and pantries and also to meters and fuse-boards.

WASH HOUSES

193. We recommend the provision of a 60-watt lamp or one *B.S.* 3 mantle in a position over the wash boiler.

FRONT AND BACK DOOR LIGHTING

194. Special lighting outside external doors is desirable when such positions are not adequately lighted from other sources such as through glass panels in or around the doors. This is particularly the case where there are steps outside such doors. Where external lighting is provided it may conveniently be arranged to illuminate the name or number of the dwelling.

GARAGES

195. We recommend that one fixed light should be provided in all garages. An additional outlet for the use of a hand lamp is desirable.

THE EFFECT ON COST OF THE ABOVE RECOMMENDATIONS FOR IMPROVED STANDARDS OF ARTIFICIAL LIGHTING IN DWELLINGS

196. The additional cost over pre-war standards as revealed by the survey will include an increase in both capital and running costs.

197. *Capital Cost.* The increase in capital cost will be due to:

a. Additional wiring or piping, etc.
b. Additional fittings.
c. Additional and larger lamps or mantles.

Estimates have been made of the cost of (a) and details are given in Appendix VII. The increase over pre-war standards, based on pre-war rates, is likely to be of the order of £5 per dwelling.

The increase due to (b) and (c) is difficult to estimate with any accuracy, but it is considered that it need not be a serious item if good, simple fittings are available.

198. *Running Cost.* The increase in running cost will depend upon the type of tariff and rate of charge per unit or therm. Some estimates for varying rates per unit or therms are given in Appendix VII. Summarized these lead to the conclusion that for a small house using type "A" fittings and including the use of one local light in the living room the increased cost would be of the order of 13*s.* per annum for each 1*d.* per unit charge for electricity or 2*s.* 6*d* per annum for each 1*d.* per therm for gas. (It must be remembered, of course, that one unit of electricity does not equal one therm of gas.) For larger houses the increase would be a little higher and for "B" and "C" type fittings there would be a further increase. There would also be a small addition due to the increased cost of renewing rather more and larger lamps and mantles.

SUMMARY OF RECOMMENDATIONS FOR LIGHTING OUTLETS

199. This is given in Table 8.

TABLE 8. SUMMARY OF RECOMMENDATIONS FOR NUMBER OF LIGHTING OUTLETS

ROOM	NUMBER OF FIXED LIGHTING POINTS	NUMBER OF PLUG POINTS	REMARKS
Working Kitchens and Sculleries	2 in majority of cases	—	
Living rooms	1	3	
Bathrooms	1	—	Preferably placed in relation to mirror.
Bedrooms (with furniture fixed)	2	1	One fixed light for dressing table and one fixed light for bed-head. One light to be controlled from the door and one from the bed.
(Position of furniture unknown)	1	2	Plug points arranged for probable bed position.
W.C.	1	—	Over W.C. fitment.
Private Stairs and Passages	Depends upon the plan	—	Double switching from up and down stairs with careful placing for illumination of stairs.
Cupboards, External Doors, and Meters and Fuses	Depends upon the plan	—	
Wash houses	1	—	Over wash boiler.
Garages	1	(1 desirable)	

THE EFFECT OF INTERNAL DECORATION ON ARTIFICIAL LIGHTING

200. The effect of internal decoration on the performance of a given artificial lighting system may be most marked, not only as regards the general appearance of the rooms but also as regards the actual illumination produced.

201. In an indirect lighting system any reduction in the reflection factor of the ceiling causes a proportional reduction in the illumination. For a direct lighting system the effect is not so marked but is still not negligible. Table 9 illustrates the order of these effects and shows the relative values of illumination produced by three typical lighting systems with different conditions of the decoration, the illumination with the lightest being taken as 100 per cent in each case.

202. It is therefore strongly recommended that decorations to walls and ceilings should be of high reflecting values both to improve the cheerful appearance and to give higher illumination values. In the case of floors, while the effect on illumination values may be small, the use of a light tone is most valuable in enhancing

the cheerful appearance of a room, consequently we recommend the use of light-coloured floors wherever possible.

TABLE 9. EFFECT OF DECORATION ON THE EFFICIENCY OF ARTIFICIAL LIGHTING

SYSTEM OF LIGHTING	LIGHT WALLS AND CEILINGS	DARK WALLS LIGHT CEILING	DARK WALLS AND CEILING
Direct	100	85	75
General	100	80	65
Indirect	100	75	30

REGULATIONS GOVERNING THE LIGHTING OF DWELLINGS

GENERAL

203. *The Housing Act*, 1936, Section 6, empowers local authorities in England and Wales to make and enforce by-laws relating to lighting. The following is an extract:

> 6. "By-laws as to working-class houses.—(1) The Local Authority (*a*) may, and if required by the Minister (*b*) shall, make and enforce (*c*) by-laws (*d*) with respect to houses (*e*) which are occupied, or are of a type suitable for occupation, by persons of the working classes (*f*) . . . (*i*) for securing the adequate lighting of every room in such houses."

204. So far as we are aware no general effect has been given to this clause, nor does there appear to be any parallel arrangement relating to flats, though some measure of control of natural lighting exists through other by-laws operating in England, Wales, and Scotland, as noted below.

DAYLIGHT

205. The existing position is largely controlled by by-laws governing window sizes only in relation to floor areas of the rooms concerned. Thus, for instance, the Model Bye-laws refer to windows being 10 per cent of the floor area of a room.[1] The London Building Act makes a similar condition,[2] with the additional proviso that window heads generally should be 7 ft. high. These by-laws were directed partly to secure adequate ventilation, but in so far as they relate to daylighting they were no doubt the best approach possible with the information available. It is clear, however, that in omitting reference to obstructions they cannot ensure adequate daylight. A number of representative instances were examined in the course of the survey of daylighting in flats (Appendix V), where window areas forming a proportion as high as 20 or 25 per cent of the floor area did not always ensure acceptable daylighting, and in some cases admitted no direct light whatever from the sky. Such conditions militate against health, economy, and cleanliness and should not be allowed to recur. We believe the measures outlined in our Report provide a means to prevent recurrence.

SUNLIGHT

206. No regulations governing the sunlighting of dwellings appear to be in force at the present time in this country, and our survey indicates that the position is not very satisfactory.

[1] *Ministry of Health Model Bye-laws*, Series IV, "Buildings," Clause 88.

[2] London County Council, By-laws for the Construction and Conversion of Buildings. Made by L.C.C. in pursuance of London Building Act (Amendment) Act, 1935. By-law No. 149, (2) (i) and (ii).

207. We have made recommendations for the orientation of living-room windows and for restricting obstructions to sunlighting. It is very desirable that these should be adopted in practice as soon as possible.

ARTIFICIAL LIGHT

208. Good artificial light no less than good daylight is essential to the well-being of people and cleanliness in the home, and may fairly be regarded as a service analogous to that of clean water and good sanitation. An adequate intensity of illumination and good seeing conditions should be ensured while leaving the occupier reasonable freedom in the choice of fittings. Unless somebody is made responsible for such services conditions are usually unsatisfactory, and the results of the survey showed that such is the case with artificial lighting. Conditions generally are below what ought to be considered a minimum to-day, and are much less than is required to develop a high value of visual capacity. Better standards would ensure a desirable increase in safety, efficiency, and comfort in the home.

209. In general, dwellings would not be occupied by people responsible for their erection, and in our opinion the occupiers should be protected against inadequate lighting. It is difficult to see how to secure the installation either of adequate outlets or efficient fittings without some form of effective guidance at the time the building is erected. Even this cannot by itself ensure good lighting, for, among other things, the cost of electricity or gas is an important factor in the level of illumination ultimately used. However, it would ensure that adequate facilities are available, and there seems a reasonable hope that if a good start is made proper standards will be maintained. Therefore we believe the proper course is to require the installation at the time of erection of a sufficient number of outlets, properly placed, together with suitable fittings, complete with lamps or mantles. The performance of such fittings should be covered by a British Standard. Our suggestions for the scope of such a specification are included in this Report together with our recommendations for lamp or mantle sizes. In making recommendations for sizes of lamps or mantles we have assumed these to be in accordance with *B.S.* 161 or 884, and lamps or mantles conforming to these or later British Standards should be used.

210. We would emphasize that any regulations which may be made should not be so framed as to exclude new methods of lighting.

211. We wish also to draw attention to the desirability of bringing existing dwellings up to these standards.

RECOMMENDATIONS

212. In consideration of the foregoing, we think the time is opportune to effect an improvement in the situation, and we therefore recommend that the appropriate authorities should consider the administrative means and regulations by which inadequate natural and artificial lighting in houses and flats may in future be avoided. We believe that this might be done by ensuring that the powers given by the *Housing Act*, 1936, are fully used, and in general we suggest that, in interpreting the meaning of adequate lighting, standards not less than the minimum suggested in this Report should be adopted. We consider that such powers should cover all dwellings built for sale or letting. We would not, however, wish any regulations to prevent development, and would therefore suggest that a way should be left open to experimental development by qualified designers.

PART IV. LIGHTING IN SCHOOLS

GENERAL

213. Special importance should be attached to lighting in schools. The eye of a child is a growing eye, and more susceptible to damage from deficiencies of lighting than the mature eye. Unsuitable and inadequate lighting may leave its mark on any child, affecting his comfort, efficiency, and earning powers throughout his life.

214. The condition of children's eyes has been kept under competent observation by school authorities in this and other countries for some years. Squint and myopia are the most commonly found troubles of a serious nature, though other important diseases occur occasionally and minor defects are often noted.

215. The most significant feature of children's eyesight is probably the fact that the incidence of serious defects increases throughout the period of school life, while minor defects remain constant and other bodily ailments show a steady decrease.[1] Nearly 10 per cent of all children in English schools are found to require treatment for vision, and additional numbers need to be kept under observation.[2] The total of eye defects appears to vary from a small percentage at the time children enter schools up to about 25 per cent at the age of leaving.

216. American figures support these English data. An investigation for the Chicago Board of Health showed that about 18 per cent of all school children at any one time had defects of vision, the range of incidence being from about 6 per cent on entry up to 25 per cent on leaving.[3] Another study shows that about 3 per cent use glasses in kindergarten, and about 16 per cent at school leaving.[4] Other similar data are available. More girls than boys seem to have defective vision.

217. The reason for the high incidence of visual defects is not known with certainty. In part, no doubt, weaknesses are inherited. In addition, the curriculum makes increasing demands on eyesight throughout the school period, and nutrition is probably a significant factor. What part is played by lighting cannot yet be estimated. We believe, however, that until each factor can be properly assessed all reasonable steps should be taken which might be expected to improve the situation, and we therefore lay emphasis on good lighting as an important form of insurance.

218. In the following paragraphs certain standards of both natural and artificial illumination are suggested. These are higher than the standards to which the Board of Education makes reference in their handbooks for designers,[5] but they can be attained without difficulty or undue expense, and represent the least values which we believe to be desirable.

219. In order to ensure the attainment of satisfactory standards we are anxious to see the institution of more effective control of lighting. In particular, we look forward to the extension of control to all schools, state-aided or otherwise. Control seems to us well justified in the case of buildings which will be used by the whole community, and since certain reforms of the educational system are already under consideration, it seems a suitable time to raise this important question.

[1] *The Health of the School Child*, Report of the Chief Medical Officer of the Board of Education, 1937, p. 51.

[2] *The Health of the School Child*, Reports of the Chief Medical Officer of the Board of Education, 1927, p. 15, and 1937, pp. 54 and 55.

[3] Fleischer, J., and Hoffmann, A. J., *Journal of the Illuminating Engineering Society* (*America*), 31 (1), p. 389.

[4] Marshall, M. V., *School and Society*, **53**, p. 582.

[5] Board of Education, *Elementary Schools Building* and *Secondary Schools Building*, 1936 and 1931, respectively.

220. At the same time we must refer also to existing schools. As a lighting problem these probably bulk larger, and are at least as important as new schools. Conditions in many older buildings are often unsatisfactory in the extreme, with inadequate daylight and only the most rudimentary artificial illumination. We cannot expect all old schools to be brought up to our suggested standards of daylighting, though sometimes improvements can be made. In such cases, particular emphasis should be laid on securing thoroughly good artificial lighting and improved decoration.

221. There is a natural tendency to accept existing conditions in old buildings, and the work of modernization often requires exceptional initiative and ingenuity, more especially because local conditions vary widely and there are often awkward details to be dealt with. But the renovation of old schools is urgent, and means should be found of including in a renovation programme all schools, whether in receipt of grants or otherwise.

DAYLIGHT IN SCHOOLS

THE ANALYSIS OF LIGHTING IN EXISTING CLASSROOM TYPES

222. Much can be learnt about the lighting of classrooms by the study of some existing types. The following analyses were made for the Committee by the Building Research Station, using the daylight factor protractors described in Appendix II. The curves shown on each diagram represent the lighting on a cross-section taken one-third of the way along the room. Where there are two or more glazed areas, the curves for each are shown as dotted lines, and only the composite or total lighting is shown as a solid line.

223. The first analysis (Fig. 38) is for a classroom erected about 1850 in the style of the Gothic revival. There are three windows, with tracery at the top, and set in very thick walls. The illumination varies from about 4·0 per cent daylight factor near the windows down to 0·5 per cent near the further wall, a value which corresponds to the present minimum standard of the Board of Education. It is probable that the deep reveals reduced the glare from the sky for pupils near the windows, and it is conceivable that the lighting may have appeared quite pleasant, though low in value as compared with modern schools.

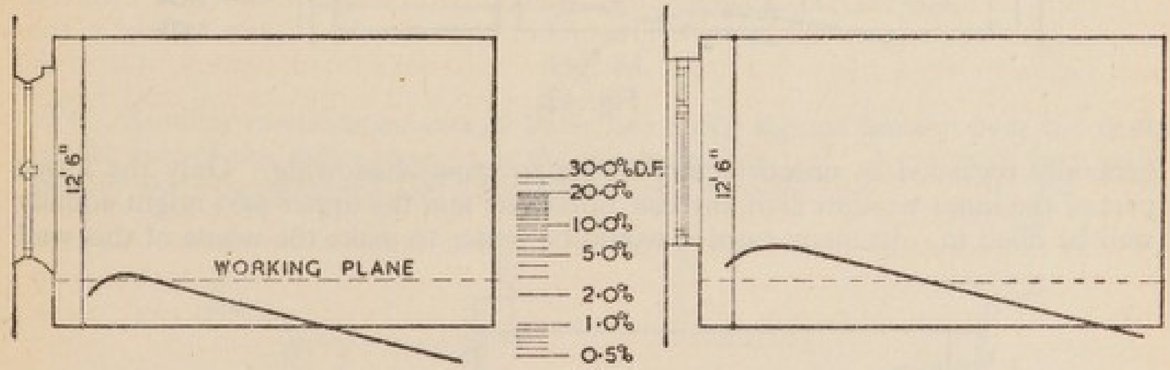


Fig. 38. Fig. 39.

224. The second classroom (Fig. 39) is from a school erected about 1910. There are four windows, designed in a Georgian manner, giving about twice the glass area of the previous case and twice the light. The gradient of illumination from window wall to furthest desks is about the same as before. The reveals are not so deep, nor are they splayed or relieved in any way.

225. The third case (Fig. 40) is a modern classroom with a more or less fully glazed external wall. The daylight factor varies from 15·0 per cent down to about 2 per cent, representing a further increase in values, but the gradient of illumination is similar to that found previously.

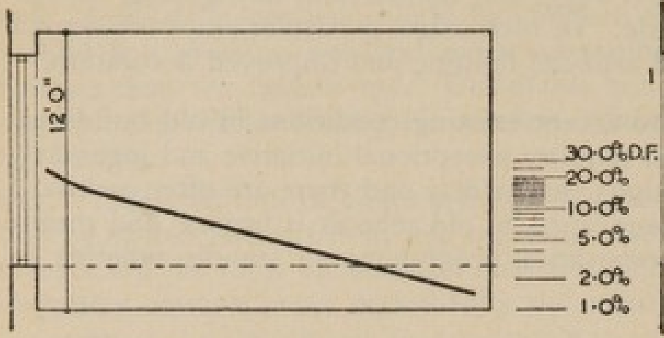


Fig. 40.

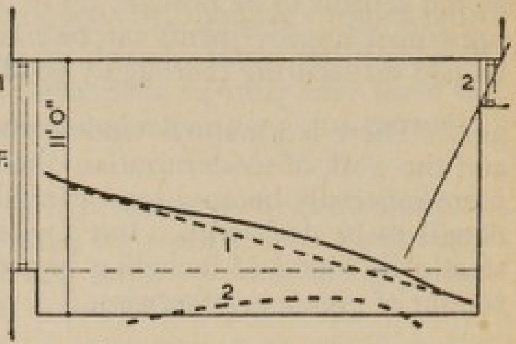


Fig. 41.

226. In single-storey schools a clerestory light is sometimes inserted above the corridor (Fig. 41). It is probably intended primarily for ventilation, though the fact that it is glazed suggests that some useful light is expected from it. In fact the angle of cut-off, as shown in this typical case, is often so great that the last row of desks receives little or no benefit, and is, by contrast with its better-lighted neighbours, thrown into apparent shadow. A large heating pipe is often fixed beneath the clerestory to reduce downdraught, and may cut off more light.

227. Borrowed light from the corridor is sometimes used (Fig. 42), but it is probably less useful than is often expected. There are two thicknesses of glass, with four surfaces susceptible to receiving dirt and two sets of window bars and piers to reduce illumination, and in addition there is the disadvantage of more or less equal light from two different directions on the last row of desks, a feature which is

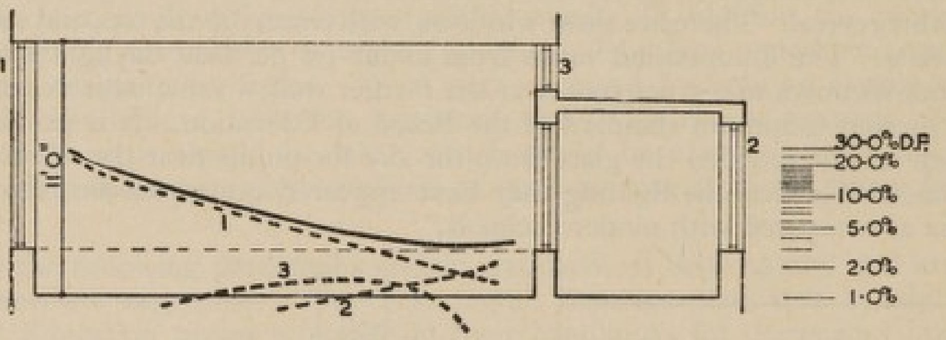


Fig. 42.

generally regarded as unsatisfactory owing to cross shadowing. Only the lower part of the inner window is of any use, of course, and the upper part might equally well be filled in. In many cases it would be better to make the whole of this wall

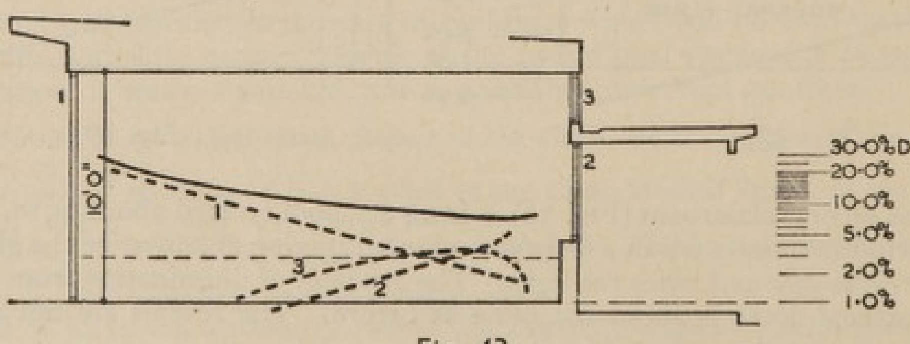


Fig. 43.

solid and use it as a reflector; it would be especially valuable at night when artificial light is used.

228. The last case examined, and the only one of these particular examples which we consider reasonably satisfactory, is from a modern school with open corridor, and a high clerestory in shallow reveals (Fig. 43). There is no doubt here that the combination has produced significantly more light, largely due to the shallow reveals in the clerestory and the narrowness of the roof of the open corridor, and the class-rooms are known to be very pleasant. The minimum illumination is about 5 per cent daylight factor. There remains, even in this case, some slight disadvantage in light from two sides.

ALTERNATIVE TYPES OF CLASSROOM FOR SINGLE-STOREY SCHOOLS

229. There are a number of possible modifications of roof design which would be expected to give important and desirable improvements of lighting to single-storey schools or to the top storey of multi-storey designs. Some of the possibilities are shown below, and we hope that school authorities will experiment with designs on these lines. As an immediate step we have suggested that experimental trial be made of the lighting of classrooms on the lines indicated in paragraphs 231 and 232.

230. The first alternative which suggests itself is to move the upper part of the windows back somewhat so that the light can reach the rear of the room more easily (Fig. 44). The improvement is clearly appreciable, though there is an unsatisfactory dip in the curve at one point. The hood is useful because it reduces the light on the desks nearest the windows without affecting those furthest away; in other words, it reduces the gradient of illumination or contrast between one part of the room and another. If the upper panel of glazing is sloped, there will be a further improvement and a tendency to smooth out the dip.

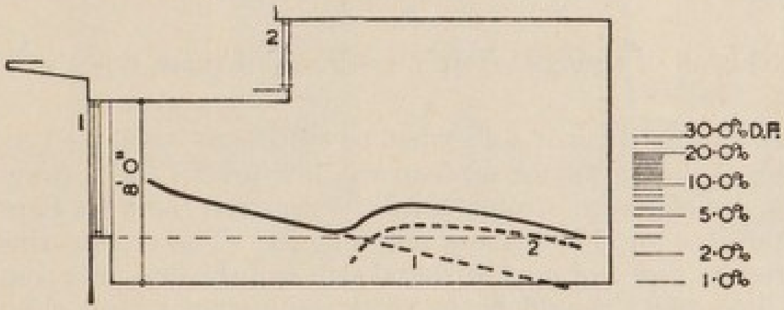


Fig. 44.

231. Another modification would be to use a side lighted lantern over the desks on the side of the room away from the windows (Fig. 45). A curve of very satisfactory shape is produced and intensities are well maintained.

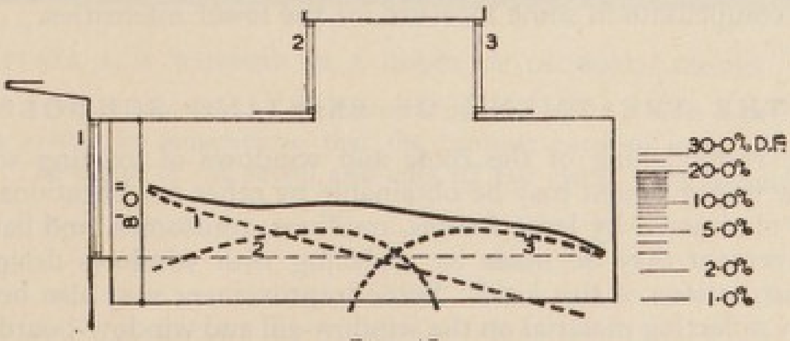


Fig. 45.

232. A third alternative—and perhaps the most important of these three—is to use clerestory lighting on both sides of the room. Two variations of this are shown (Figs. 46 and 47): the upper one is based on a simple form of roof truss, while in the lower one the shape is freely designed in order to give as flat a curve as possible. It will be seen that in each case the side windows are of less than normal height, so that the ceiling need not finally be higher than usual. With the symmetrical truss design it would be possible to fill in the trusses to form large louvres across the ceiling. These would be useful to cut off sky-glare from the children's eyes, and they can be used to advantage in the design of artificial lighting.

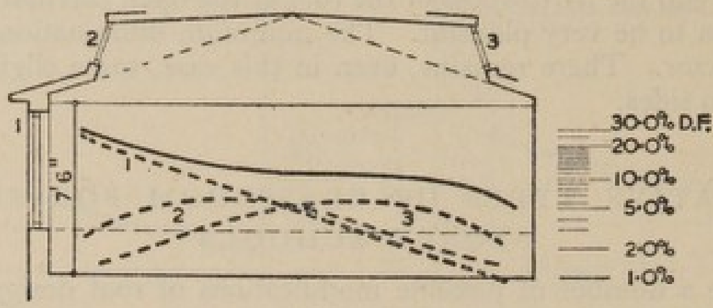


Fig. 46.

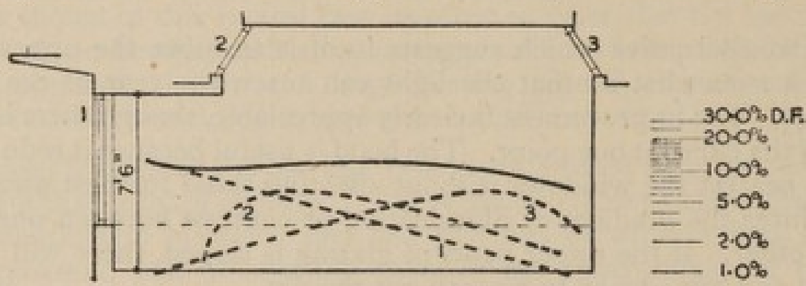


Fig. 47.

233. The exclusion of sunlight from classrooms of these types will be discussed later.

234. Another alternative is a somewhat novel design developed to make use of louvres to restore the advantage of deep window reveals for cutting off sky-glare (Fig. 48). On the plan of this room it will be seen that there are four large louvres which divide up the window glazing into lengths. The section shows that these vertical louvres are capped by a horizontal slab and the design is completed with a hood. The final effect should be to reduce sky-glare for all children near the window, and, as the curve shows, the distribution of light is also very uniform. The latter is to be expected, for louvres of this kind are bound to reduce intensity near the windows without much affecting the penetration.

In a design of this type it is clear that the values of illumination could not be as high as with roof lighting, but relatively good distribution and freedom from glare should compensate in some measure for the lower intensities.

THE TREATMENT OF EXISTING SCHOOLS

235. Where re-modelling of the roofs and windows of existing schools is not possible some improvement may be obtainable by other modifications. If existing windows are obstructed by large frames, mullions, transomes, and bars, an appreciable improvement may be made by replacing with windows designed to have minimum obstructions of this kind. Some improvement may also be obtained by using a highly reflecting material on the window-sill and window-board, particularly if these are of a fair depth.

PLATE I. A WINDOW IN A HOUSE OF GEORGIAN DESIGN

The inner reveal is splayed and the outer is painted white. Note how the tone values are graded in sequence so that the contrast between inside and out is reduced. The depth of the reveal also cuts off sky glare. (See paragraph 10.)

PLATE 2. A SEMI-DIRECT LIGHTING FITTING, WITH MOST OF THE LIGHT GOING DOWNWARD

The walls and ceiling are inadequately lighted, with a slight consequent appearance of gloominess, and with the fitting in contrast against the background. (See paragraphs 96-100.)

PLATE 3. A FITTING GIVING GENERAL DISTRIBUTION

Contrast is reduced, and the room appears brighter. (See paragraphs 96-100.)

PLATE 4. AN INDIRECT FITTING, WITH ALL THE LIGHT DIRECTED UPWARD

Distribution is adequate, but the ceiling is now the brightest thing in the room. Wholly indirect lighting is often found uninteresting because of the poor sense of modelling and form it causes. (See paragraphs 96-100.)

PLATE 5. THE BRITISH STANDARD STUDY LAMP DESIGNED TO GIVE A WELL-BALANCED DISTRIBUTION OF LIGHT UPWARD, DOWNWARD, AND SIDEWAYS

(See paragraph 17)

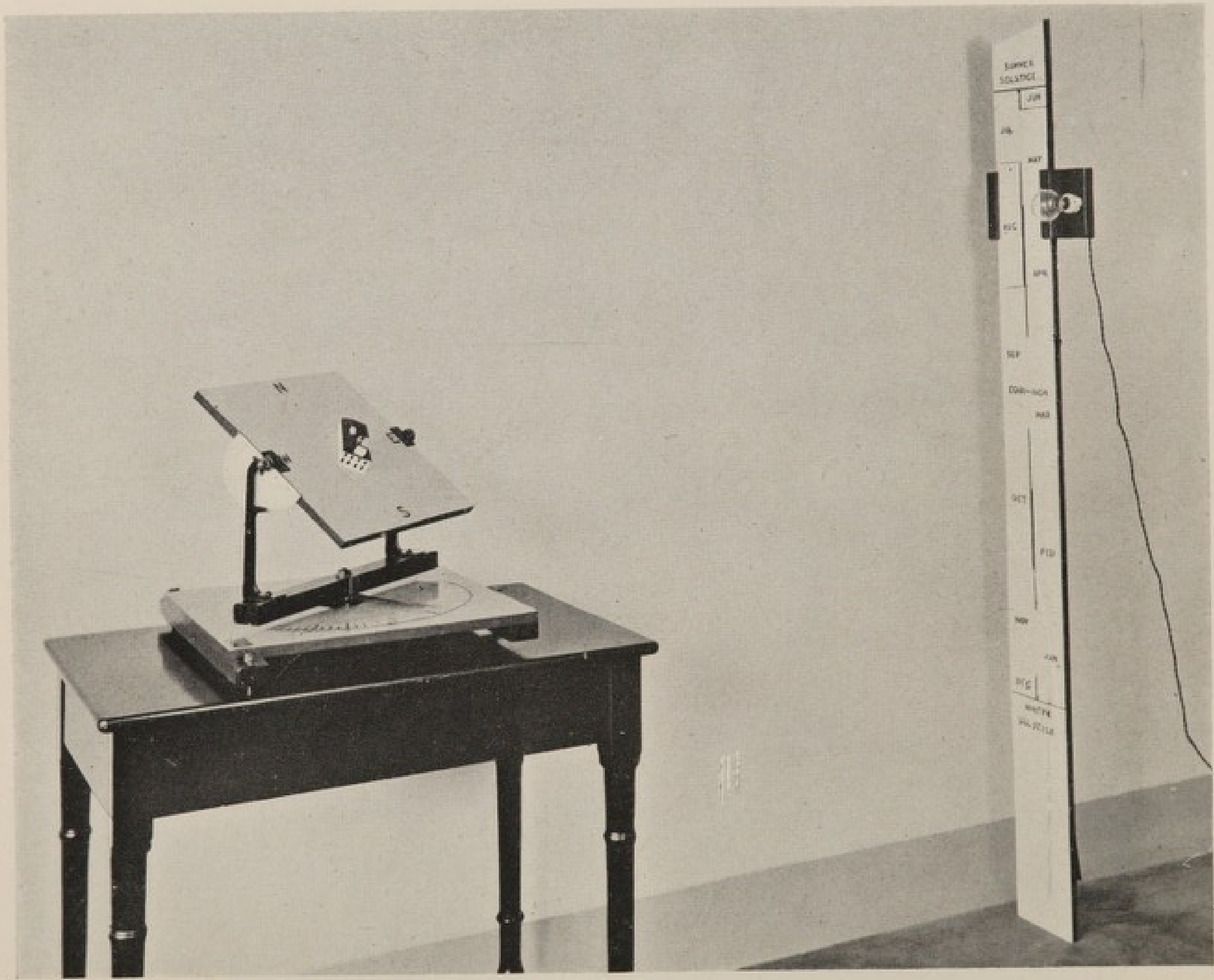
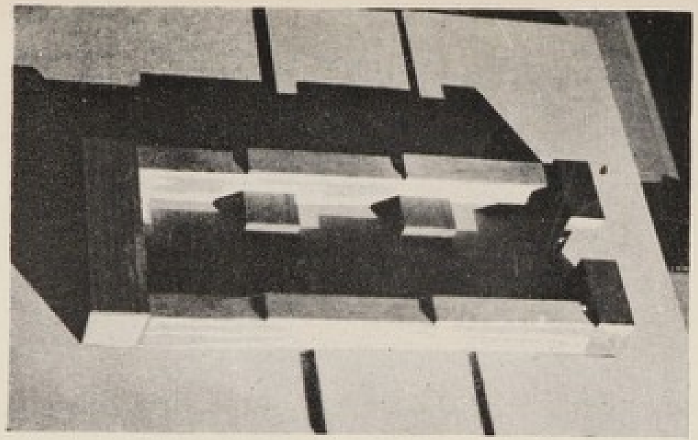
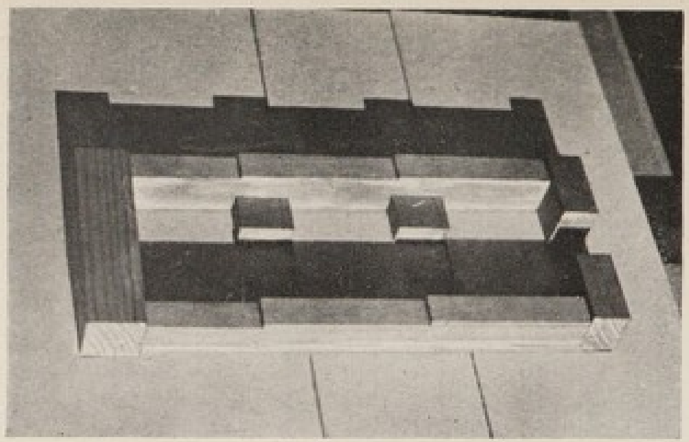


PLATE 6. THE HELIODON

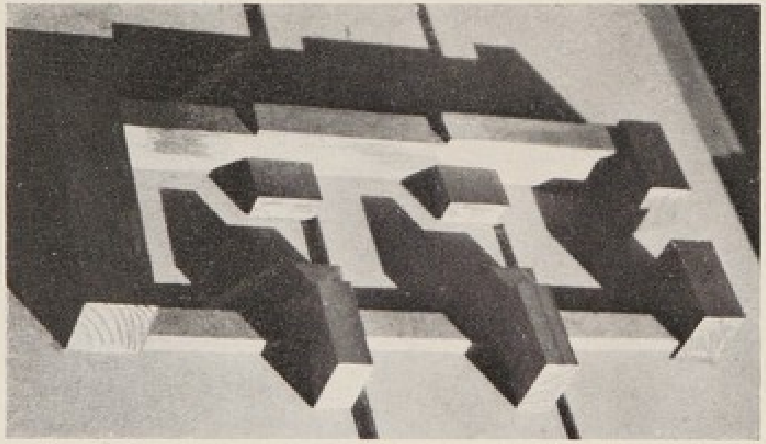
See Appendix III

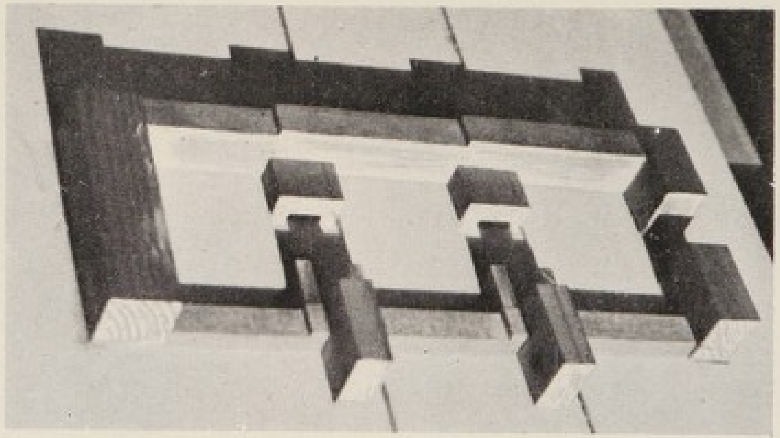




10.00 a.m. (2.00 p.m.) A Noon

THE ORIGINAL SCHEME, WITH SUNLIGHT AS FOR OCT. 31ST OR FEB. 15TH.
IN MIDWINTER THE WHOLE CENTRAL AREA WOULD BE SHADOWED





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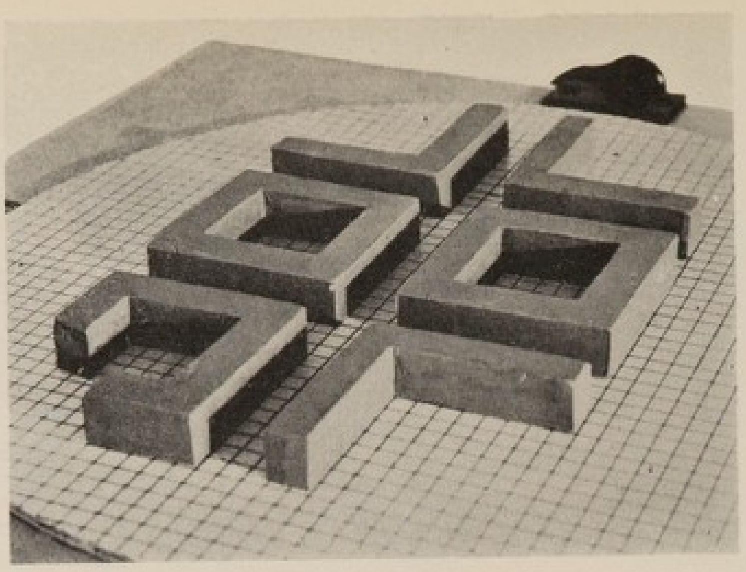
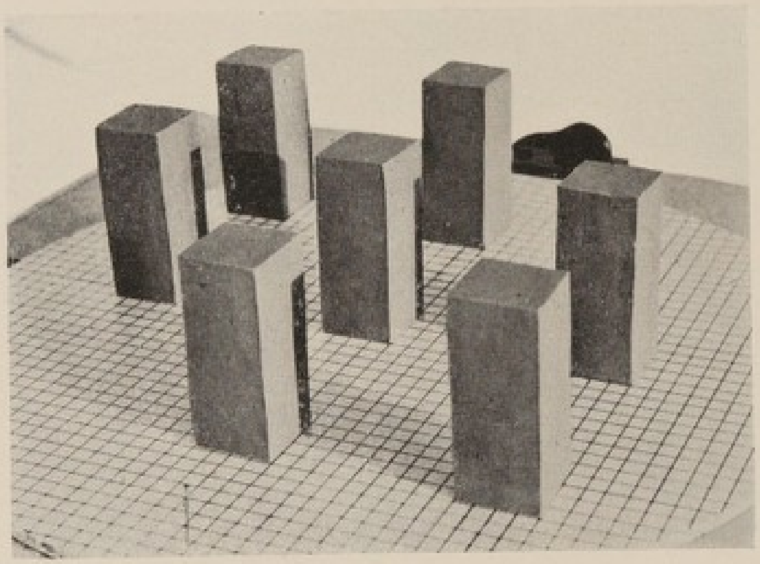
THE PROPOSED REVISION

PLATE 7. (See Appendix III)



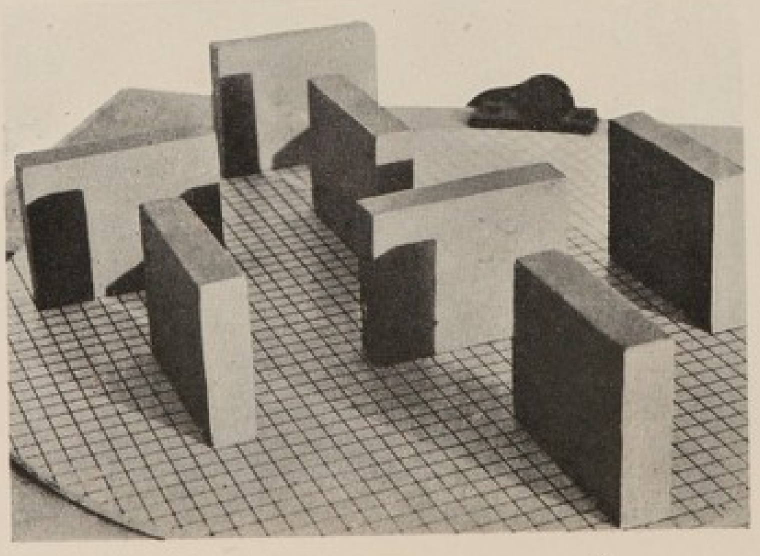
A

Winter sunlight on typical building shapes



B

Winter sunlight on an alternative type of structure offering the same overall density. (Note the free insolation of the ground and buildings.)



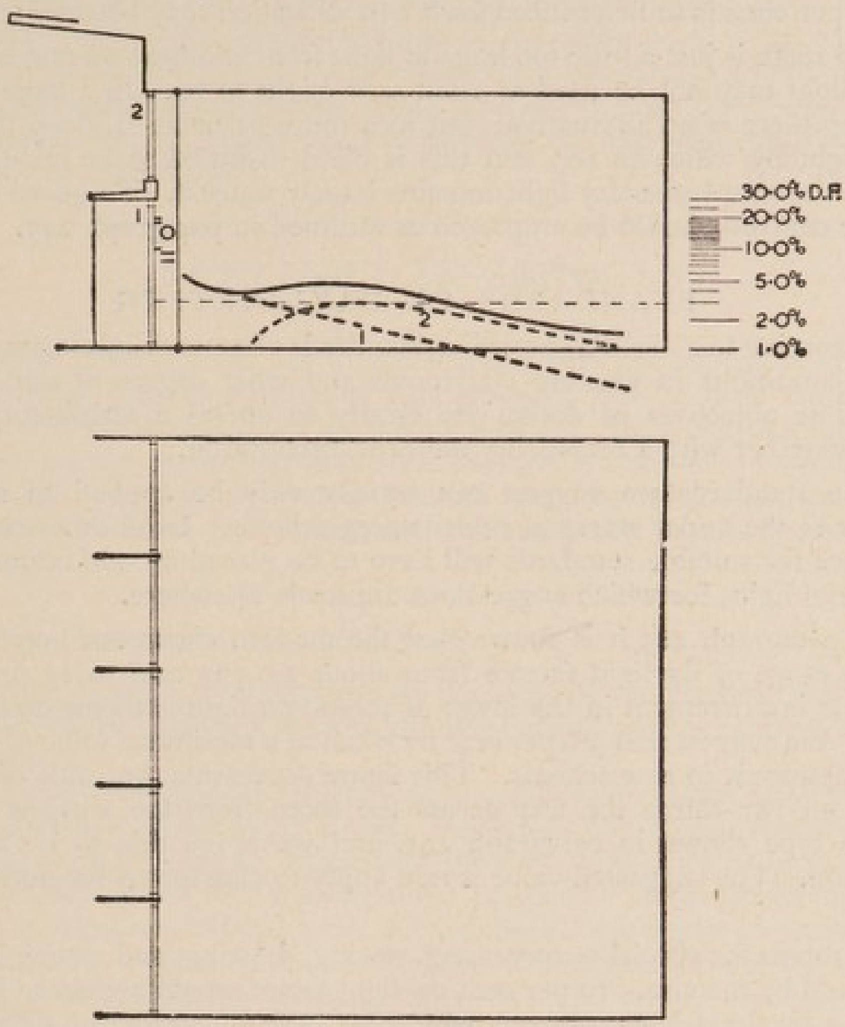
C

Winter sunlight on an arrangement of buildings which was found appropriate for good daylighting. (Note how the broken shadow permits the insolation of lower storeys.)

PLATE 8

(See paragraphs 78-81)

In the case of single-storey schools, the use of a light-coloured terrace on the ground outside the windows might result in improvement if the surface can be maintained reasonably light in colour. For a useful result to be obtained by this method the reflector would have to be fairly large. With both this and the above method using a reflecting sill the ceiling of the room acts as a secondary reflector and must therefore be as light in colour as possible.



PLAN

Fig. 48.

236. Where conditions in existing schools cannot be brought up to reasonable standards by some of the above methods the only solution will be to depend substantially upon artificial sources of light as a temporary measure pending the demolition of the building. In such cases the artificial lighting installation will be a most important factor and the suggestions made in paragraphs 246 and 247 should be considered. Evidence so far presented to us does not suggest that special types of glass would be likely to be of any assistance in such cases.

MULTI-STOREY SCHOOLS

237. It will be clear that classrooms in multi-storey schools are limited to daylight from one side only plus the very small addition of light which may come across corridors, unless recourse is made to a symmetrical or unusual design of structure, for instance, in which successive storeys are offset so that clerestory lights can be provided in each room. For classrooms of normal depth it would not be possible to obtain the desirable standards of lighting unless the ceiling height is somewhat greater than the usual 11 ft., and where this increased height is not

obtained it would be necessary to use an admixture of artificial light. As noted later, the switching of artificial light should then be arranged so that the bank of lights farthest from the window can be used separately. The artificial light should be designed to mix with daylight. A much more satisfactory arrangement would be to make the classrooms rather shallower, in which case acceptable daylight may be obtained from lighting on one side only. It is hoped that if the number of pupils per class is to be reduced such a modification may become possible.

238. If a room is just a little too large to light from windows on one side only, the artificial light may not be used as often as it ought to be. In a large room 50 or 60 ft. deep there is no alternative; but in a room 21 or 22 ft. deep there may be enough light by which to see, and this is often assumed to be enough for good vision, so the supplementary light remains largely unused. To guard against this, automatic controls should be employed as outlined in paragraph 247.

STANDARDS OF DAYLIGHTING

239. In coming to a decision regarding standards of natural lighting we have borne in mind conditions in existing classrooms and what degree of satisfaction they afford. The objectives of design are clearly to obtain a satisfactory minimum intensity together with a reasonably uniform distribution.

240. The standards we suggest can usually only be applied to single-storey schools or to the upper storey of multi-storey schools. In all other circumstances dependence for suitable standards will have to be placed on admixtures of natural and artificial light, for which suggestions are made elsewhere.

241. In paragraph 225 it is shown that the modern classroom may be expected to have a range of daylight factors from about 2·0 per cent to 15 per cent. An appreciable improvement in the lower of these two figures seems desirable and is possible. We suggest that 5·0 per cent be taken as a minimum value of the working area of classrooms in new schools. This figure represents the value of daylighting found about two-thirds the way across the room from the window wall of the classroom type shown in paragraph 225, and we judge this to be a reasonable illumination. The suggested value would apply to classrooms for normal teaching work.

242. In rooms for special purposes, *e.g.* sewing, drawing, and machining, a higher value should be the aim. 10 per cent daylight factor would appear to be a suitable figure, and by the design approach which has been illustrated no difficulty would be found in reaching such a value in single-storey schools or on the top floor of multi-floor buildings.

243. Maximum values should not exceed minimum values by too great an amount; the aim should be to limit the ratio of maximum to minimum value to 2 : 1 or less.

244. No areas of glazing should be placed in the direct line of vision of teacher or pupils; this will generally mean avoiding windows in front and rear walls or roof lights which run across the room rather than parallel to the side walls. An exception could always be made where screening by louvres is effectively employed.

METHODS OF ANALYSIS AND DESIGN

245. The design and analysis of natural lighting in classrooms should offer no exceptional difficulty by any of several methods outlined in Appendix II.

COMBINATION OF ARTIFICIAL AND NATURAL LIGHT IN SCHOOLS

246. In most classrooms it will be necessary to supplement daylight with artificial light for considerable periods in winter: in such classrooms the use of artificial light resembling daylight in colour is advantageous.

The lights should be arranged so that it is possible to use those fittings lighting the dark part of the room without necessarily using the complete installation. In rooms with windows along one side only, the obvious arrangement is lines of fittings running parallel to the window wall, each line to be separately controlled.

247. There is much to be said for photo-electric control of lighting so that the personal element is not involved in judging the need for light. Such devices can be arranged to control the lighting of parts of the room to meet the requirements mentioned in paragraph 246, and one control gear can control a number of rooms having similar conditions of natural light. The use of such photo-electric control is recommended for all classrooms for partially sighted children and elsewhere when the cost is reasonable.

SUNLIGHT IN SCHOOLS

GENERAL

248. Sunlight in classrooms has to some extent been the subject of controversy. On the one hand it can be a source of very annoying glare, but on the other hand the warmth and pleasure it gives are widely desired. We think that on the whole there will be general agreement that some sunlight is desirable in winter in classrooms and that it is probably preferred in the morning rather than the afternoon. In summer the problem is reversed, and the regulation of sunlight seems to be the aim.

THE ADMISSION OF WINTER SUNLIGHT

249. It is not difficult to determine, on the basis of the general data previously given about sunlight (paragraphs 61 to 68), what are acceptable limits of orientation for classrooms.

In the case of dwellings we recommended a minimum of one hour of sunshine during the afternoon in the living rooms. For school classrooms, excepting, say, art and drawing rooms, we see no reason why the time should not be increased to two hours. Considering the fact that windows of schools are generally much wider than those of domestic buildings the cut-off due to the depth of reveals is likely to be very little. To obtain this two hours of sunshine during the school day suitable limits of orientation would be E. to W. To ensure the sunshine penetrating into the room during the morning, which may be desirable from the heating point of view, the orientation would have to be limited to E. to S. or perhaps tending towards S.W. (Fig. 49).

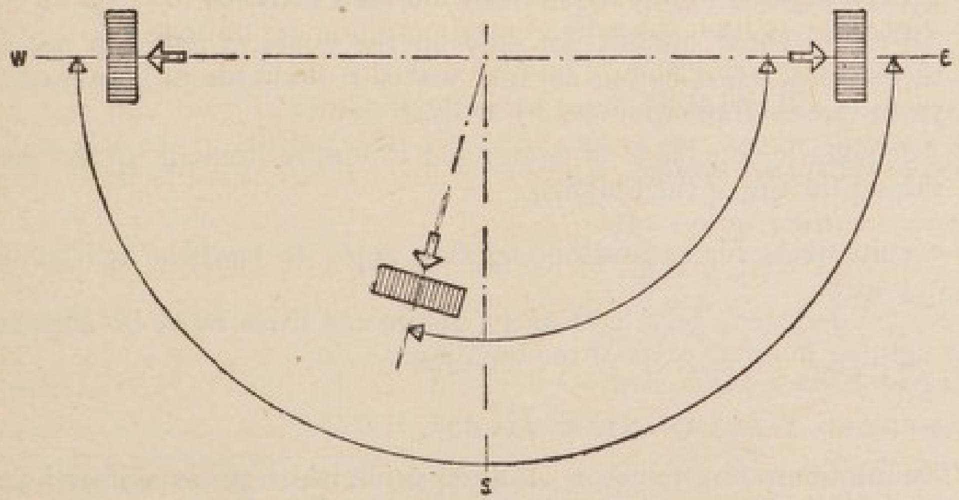


Fig. 49.

THE REGULATION OF SUMMER SUNLIGHT

250. In schools the regulation of summer sunlight is a problem of considerable importance.

The first measure which may be suggested is the use of hoods over side windows, to which reference has already been made, for the reduction of peak intensities of daylight near windows. The low angle winter sun can penetrate beneath such hoods without difficulty, but summer sun, which rises to angles of over 60° in this country, can be successfully excluded.

For clerestory windows, which have been suggested for daylighting, permanent hoods could not be employed. However, blinds, temporary summer hoods or awnings, or special hoods made of louvres, or gratings to fix over the windows, are available and any or all of these could be used.

ARTIFICIAL LIGHT IN SCHOOLS

GENERAL

251. Our recommendations for the artificial lighting of schools are confined to general principles because, without having information as to the exact nature of post-war schools, it is not possible to make detailed suggestions. Moreover, we consider that it is essential that each installation should be designed by qualified lighting engineers, following the general guidance given in this Report.

Good practice should usually follow the I.E.S. or other recognized Code of Practice, and any such code should be kept up to date to embody changes which investigations and experience prove desirable. In this Report we refer to certain minimum standards below which we consider post-war practice should on no account fall.

LIGHTING REQUIREMENTS

252. The main requirements in teaching rooms are:

- a. An adequate standard of illumination on the work which is being viewed (*e.g.* books, chalkboards).
- b. Proper design and placing of light sources so that they do not cause distracting glare.
- c. Satisfactory direction and suitable colour of lighting.
- d. Suitable decoration to ceilings, walls, floors, and furniture.
- e. Special lighting to suit requirements of certain rooms.
- f. An arrangement suitable not only for the hours of darkness but also for those times when failing daylight makes it desirable to light parts of the room remote from windows by artificial light.
- g. Adequate maintenance of equipment to ensure keeping up the standards during the life of the building.

The requirements for satisfactory lighting apply to teachers and lecturers as well as to pupils.

In addition to satisfactory lighting to classrooms there must be adequate and suitable lighting in other parts of the building.

RECOMMENDED ILLUMINATION VALUES

253. The minimum service values of illumination which we recommend are given in Table 10. In order to achieve these the design values should be for illumination 40 per cent above the service values.

TABLE 10. MINIMUM SERVICE ILLUMINATION VALUES FOR SCHOOLS

	ILLUMINATION IN F.C. OVER WORKING AREA [1] AT 2′ 9″ ABOVE FLOOR LEVEL EXCEPT WHERE OTHERWISE NOTED	NOTES
Normal Classrooms	12	Chalkboards should have a vertical illumination equal to the horizontal illumination over the main working area of the room. This will require either special local lighting or a higher general illumination over the demonstration area. Such higher illumination is also of value in holding the attention of the students. For this latter purpose the increase should be of the order of 50–100% above the illumination elsewhere in the room.
Laboratories Workshops Art Rooms Sewing Rooms Drawing Offices	12	With supplementary lighting of higher values to suit the layout of rooms and machines. Lighting of workshops and similar trade rooms should be as used in the best industrial installations. In sewing rooms, too highly diffused lighting is not desirable and there should be a reasonable measure of directional lighting. Where colour discrimination is necessary artificial daylight units should be used.
Assembly Halls	6	It is recognized that the assembly hall is generally designed to be specially attractive and distinctive in appearance. For this reason as few restrictions as possible should be placed on its lighting and decoration, but the general principles outlined earlier in this Report should be followed. Where halls are likely to be in frequent use as classrooms or for examinations the lighting should be up to classroom standards. Usually, special provision for stage lighting is needed and in some cases other special lighting may be required, *e.g.* for badminton or other games. The height and size of assembly halls may make additions or alterations an expensive matter. It is therefore well to be somewhat lavish in the initial installation.
Staffrooms	6	With local lighting in addition.

Note: It is assumed that adequate provision will be made for the increasing use which is now being made of lantern and cinema projecting apparatus.

[1] The " working area " is intended to mean the area within which the desks or workplaces are situated.

TABLE 10—(*continued*).

	ILLUMINATION IN F.C. OVER WORKING AREA [1] AT 2′ 9″ ABOVE FLOOR LEVEL EXCEPT WHERE OTHERWISE NOTED	NOTES
Libraries		
a. Backs of books (on vertical surface)	3	Tables may be lighted locally.
b. General area	6	
c. Tables	12	
Corridors and Stairs	3	The general principles given in Part III of this Report, paragraphs 190–191 and 194, should be followed.

THE DISTRIBUTION AND DIRECTION OF LIGHT

254. Within the seating area of a room the maximum illumination should not exceed 1·5 times the lowest value. Outside the seating area the illumination should not fall below 50 per cent of the minimum values of the seating area.

255. The lighting installation should be designed to give a bright and cheerful appearance, and an important point in this connection is to have some light falling upon the ceiling and upper walls. No precise figure can be given for the proportion of light to be directed in this way, but it should be sufficient to prevent undue contrast between any fittings and the background against which they may be seen.

BRIGHTNESS OF LIGHT FITTINGS

256. The following recommendations apply to all classrooms and lecture theatres in which the student is viewing a chalkboard or writing or reading at a desk.

No luminous part of a light fitting should be less than 9 ft. above the floor level immediately below the fitting. Where a fitting is mounted less than 16 ft. above floor level the brightness should not exceed 5 c./sq. in. for any direction of view between the horizontal and 45° below the horizontal. It is preferable, however, that the brightness should be considerably less than this, say, 2 to 3 c./sq. in.

The above brightnesses refer to the maximum value for any 1 sq. in. of surface in the given direction of view.

When a fitting is mounted more than 16 ft. above floor level the installation should be specially designed but no limits are placed on brightness values.

It is not possible to specify the brightness of fittings used for such special purposes as spotlighting, but the fittings should, so far as possible, be placed so that they do not distract the student.

PARTIALLY SIGHTED CHILDREN

257. Wherever possible, partially sighted children should be taught in classrooms with special lighting installations and a level of illumination at least twice that of the minimum for ordinary classrooms is recommended, in spite of the fact that this will often require a more complex system of lighting than the normal in order to get the higher values of illumination without accompanying glare: the brightness of fittings should not be greater than for ordinary classrooms.

In such classrooms more than ordinary attention should be given to comfort conditions in removing the possibility of reflected glare, etc., so that pupils are able to use their eyes with the miminum of fatigue. The use of special books will also be advantageous.

Where special classrooms cannot be provided, partially sighted children should be placed in positions to give them the maximum benefit of the lighting installed.

PLAYGROUNDS

258. Before the war a number of playgrounds were lighted in order to provide attractive places for children after the hours of darkness, and it is probable that the value of this practice will be more widely recognized in future. In such cases, while no part of the playground so used should be in darkness it may be sufficient to concentrate the lighting mainly in one area. For this purpose the use of lights in reflectors, placed at least 24 ft. and preferably 30 ft. above ground, has been found to be effective. These lights should be sited along the side of the playground, either on poles or possibly on the building and at distances not more than 60 ft. apart between fittings. An allowance of approximately one-third of a watt per sq. ft. or 10 B.Th.U. of gas per hour per sq. ft. of area should be sufficient to encourage children to come and play in the playgrounds instead of the streets, and in the immediate vicinity of the lights would probably be sufficient to allow of practising passing at netball, and similar training. If lighting sufficient for organized games is required a more elaborate installation would be necessary and should be carefully designed for the particular circumstances.

FLOODLIGHTING

259. Where the façade of a school and its location are suitable some consideration might well be given to the desirability of floodlighting the exterior. In some cases the whole façade might be lighted, in others it might be more suitable to light some feature such as the entrance block or assembly hall or a flagstaff. It is suggested that such lighting would be useful in emphasizing to both pupils and the public the importance of the school building as an essential unit in a community.

MAINTENANCE

260. The importance of good maintenance can hardly be over-emphasized. All broken or burned-out lamps or mantles should be replaced immediately, and adequate arrangements should be made for the cleaning of fittings at reasonable intervals. The appropriate intervals for such cleaning will vary according to local conditions. In order to ensure that the minimum recommended values of illumination are maintained, we recommend that arrangements should be made for routine inspection, by a competent inspector of the appropriate authority concerned, to be carried out at least three times a year, and that for this purpose light meters should be used. It should be noted that such light meters will require periodic calibration.

In making our recommendations we have assumed that re-decoration will be carried out at reasonable intervals. Unless this is done both appearance and effectiveness will be seriously reduced.

DECORATIONS IN SCHOOLS

261. The principle to be followed is that decorations should be light and cheerful in appearance. Use should be made of highly saturated colours in borders, dadoes, etc. to relieve the monotony of the more usual creams and buffs, and the same colour system should not be carried throughout a school. Matt or semi-gloss finishes should be used as far as possible to avoid stray, specular reflections.

262. Ceilings should be light in colour and should have a reflection factor of not less than 70 per cent. This permits the use of several shades other than white, and these other colours can be used with advantage.

263. Walls above dado height should be fairly light and should have a reflection factor of not less than 50 per cent. Below dado height a reflection factor a little less than that of the upper walls is desirable, and a 30–50 per cent reflection factor should be obtained. In addition to concealing marking of the walls this breaks the monotony.

264. Floors and floor coverings play an important part in the appearance of a room and they should be as light in colour as possible, consistent with other requirements.

EQUIPMENT IN SCHOOLS

265. Chalkboards in most common use are black. Some teachers consider that coloured chalkboards have a somewhat better appearance, reduce specular reflection, and contrast between the board and background. Yellow boards with blue chalk have been used with some success but other colours are also possible. It is important that all boards should be kept well cleaned. Lighting fittings should be arranged to avoid specular reflection, and a special local light will often be the best way of achieving this result.

266. Desks should preferably be light in colour and have a matt surface.

267. Books and writing paper should, as far as possible, have matt surfaces, as glossy surfaces give rise to difficult seeing conditions. A good clear type should be used, and our suggestions for illumination values are based on the assumption that type will be not less than 10 point combined with good spacing.

268. In all rooms where artificial lighting is likely to be required there should be window blinds, and these should have a light inner surface with a reflection factor similar to that of the walls. Similarly, where opaque window blinds are needed the inner surface should be light in colour.

269. Where episcope projection is likely to be used it will probably be necessary to arrange for total darkening of the room, but with diascope projection partial darkening may be sufficient and an arrangement of light switching to allow for this may be advantageous.

PART V. EDUCATION OF THE DESIGNER AND THE LAY PUBLIC

GENERAL

270. Although much could be done by suitable regulations for lighting practice such as have been outlined, the full benefit can be obtained only when both the professional man and the lay public are well informed on the subject. Education to this end has been neglected in some respects and we make certain suggestions for improving the situation.

THE DESIGNER

271. Two professions, architecture and illuminating engineering, are involved in the lighting of buildings, and for the development of good practice it is clear that in their education they should find common ground. The engineer requires, in addition to his knowledge of the illuminant and the principles of lighting design, some understanding of building practice and the nature of architectural form. His is one of several professions which contribute to the final form of a modern building, but his contribution can only be partly effective if he is unable to understand the problems and share the outlook of the architect. The latter, for his part, is equally handicapped if he does not grasp the principles and possibilities of lighting, for he is unable either to conceive a fully-developed design or criticize the proposals of his consultants.

272. It does not appear that in the two professions these objectives are adequately met. We therefore recommend that the importance of including natural and artificial lighting of buildings among the subjects to be studied for qualifying examinations be brought to the notice of:

a. The Board of Architectural Education set up under the Architects (Registration) Act, 1931.
b. The Council of the Town Planning Institute.
c. The Council of the Institution of Municipal and County Engineers,

and that the attention of the Council of the Illuminating Engineering Society be drawn to the need for ensuring that in their training lighting engineers should receive suitable instruction in building practice and design.

THE LAY PUBLIC

273. Education of the lay public should take many forms. In schools and colleges children and young people ought to be taught proper care of the eyes, and through good lighting in the classrooms they can be given an example which will enable them to appreciate the need for adequate lighting elsewhere. The householder can be greatly helped by housing managers and by the supply authorities, in their demonstration showrooms. The latter should take particular care to ensure that people see the performance of fittings, and not merely their outward appearance as one fitting among several others. Emphasis should also be laid upon the value of proper maintenance of lighting installations.

BOOKS AND PAPERS ON LIGHTING

274. There is available a considerable volume of written information on Lighting. The following very brief list is included as an indication of a few books and papers which are considered of particular interest in addition to those referred to in the text of this Report:

Walsh, J. W. T., "Planning for Daylight." *Transactions of the Illuminating Engineering Society*, Vol. VII. No. 2, Feb. 1942.

Bulletin of the Health Organisation of the League of Nations, Vol. VII. Extract No. 11.

"Comité d'études sur l'éclairage diurne." 1932.

D.S.I.R. Illumination Research Technical Paper No. 7 (2nd edition), *Penetration of Daylight and Sunlight into Buildings*. (H.M. Stationery Office.)

Modern Electrical Illumination, C. Sylvester and T. E. Ritchie. (Longmans, 1927.)

A Symposium on Illumination, edited C. J. W. Grieveson. (Chapman & Hall, 1935.)

Light, Photometry and Illuminating Engineering, W. E. Barrows. (Second edition.) (McGraw-Hill, 1938.)

The Scientific Basis of Illuminating Engineering, P. Moon. (McGraw-Hill, 1936.)

The chief papers on lighting practice published in the English language appear either in the *Transactions of the Illuminating Engineering Society*, published at 32 Victoria Street, S.W.1, or in *Illuminating Engineering*, the corresponding American publication, incorporating the *Transactions of the American Illuminating Engineering Society*. In the latter publication there are three papers dealing with the application of modern ideas in lighting to domestic premises. These are:

"Custom-built Lighting Enters the Home," by I. C. Wood, Vol. 27, 1932, p. 611.

"Modern Lighting in a Modern Home," by E. W. Commery, Vol. 32, 1937, p. 933.

"Fluorescent Lamp Applications in the Home," by M. Fahsbender and R. G. Slauer, Vol. 35, 1940, p. 669.

PART VI. RECOMMENDATIONS FOR FUTURE RESEARCH

275. We have included in our Report the results of recent investigations regarding the siting, layout, and height of buildings as they affect daylight and sunlight. We recommend that these studies should be continued. (Further investigation is needed before all the implications can be seen.) It would be desirable to reach a stage where it is possible to specify the external conditions under which the admixture of natural and artificial light may be regarded as a basis for the design of buildings.

276. We have referred to the admixture of natural and artificial light and consider that the possibilities opened up by new artificial sources should be examined. In particular the value of illumination by artificial light which is to be mixed with daylight should be examined.

277. Almost all illumination values quoted at this time are based on experience, and a systematic examination is required to determine these values on a fundamental basis.

278. Considerable further study is desirable of the problem of artificial light source brightness in relation to comfort, health, and efficiency under different durations and other conditions of exposure.

279. Certain claims are made as to the usefulness of diffusing and re-directive glasses for window glazing. We would welcome a full study which would make possible an assessment of the value of such glasses.

280. We have noted the high proportion of children developing eye defects during school life and have pointed out that it is not at present possible to say what factors are responsible. We consider that research on this is urgently required. We have made certain suggestions for the improvement of lighting in schools, and we consider that the results of developments on these lines should be studied.

281. We suggest that an inquiry be made into the possibility of carrying out an investigation of the effect of lighting on the work of school children.

PART VII. SUMMARY OF CONCLUSIONS

GENERAL

282. 1. The terms of reference are briefly:

i. To review existing information and practice.
ii. To make recommendations for post-war practice.
iii. To make such recommendations for future research as suggest themselves in considering (i) and (ii).

2. Attention so far has been confined to a study of the general principles of lighting and their application to dwellings and schools. The following are our main conclusions:

EXISTING INFORMATION AND PRACTICE

3. While the fundamental principles of lighting, both natural and artificial, are well established, the knowledge of these principles is not sufficiently widespread and has not been put to full use in general practice. This applies strongly to natural lighting as well as to artificial lighting. (Paragraph 1.)

4. Existing practice has, in general, paid insufficient attention to the quality of lighting: both quality and quantity are important and are interdependent. (Paragraphs 1, 2, 4–18.)

5. The lighting of many dwellings and schools is unsatisfactory, and this is due very largely to the lack of recognized standards and means for their adoption. This has been shown very clearly in the case of dwellings by the results of the lighting surveys. Agreed standards will do much to remedy these defects. (Appendices V and VI, and paragraphs 215-228, 241.)

RECOMMENDATIONS FOR POST-WAR PRACTICE

6. Steps should be taken to ensure a wider understanding of available information on lighting. (Paragraphs 270-271.)

7. The Board of Architectural Education and the Town Planning Institute should include a study of lighting in the subjects for their qualifying examinations. (Paragraph 272.)

8. The training of Illuminating Engineers should include suitable instruction in building practice and design. (Paragraph 272.)

9. Efforts should be made to give the general public a better opportunity of appreciating the importance of the provision and maintenance of sufficient and suitable lighting. Teaching in schools and colleges should include instruction on the need for care of the eyes and the value of good lighting. Fittings for sale to the public should conform with the requirements of a Code of Practice or Specification containing details of the distribution and output, which will enable the buyer to judge of the performance of the fittings as well as of their appearance. (Paragraph 273.)

10. Standards of lighting, both natural and artificial, should be laid down for various classes of buildings, and in particular recommendations are made for dwellings and schools. (Paragraphs 107–202, 239–244, 252–260.)

11. *Recommendations for Dwellings*. The appropriate authority should consider the administrative means and regulations by which inadequate natural and artificial lighting in houses and flats may be prevented. This might be done by ensuring that powers such as those given by the *Housing Act* 1936 are applied to all dwellings. In interpreting the meaning of adequate lighting, standards not less than the minima suggested in Part III of this Report should be adopted. (Paragraphs 203–212.)

12. Standards of daylight for different types and sizes of rooms are given in terms of two requirements:

i. A minimum area of the room lighted to a given daylight factor.

ii. A minimum penetration into the room of such daylight. (Paragraph 107.)

13. The methods of calculation for providing such conditions are fully explained, and special attention is called to the possibility of using Tables of window performance. (Paragraphs 116–124 and Appendix II.)

14. Account must be taken of the degree of external obstruction to windows and due allowance made when deciding upon their size, shape, and position. (Paragraph 116, also Part II generally.)

15. With regard to sunlight, the wish of the people to have some sunlight in their houses seems in itself sufficient justification for a recommendation for a minimum standard. Such recommendation has been made. (Paragraphs 65, 137–151.)

16. Since external obstructions affect the daylight and sunlight available, a study of the site and town planning aspects is necessary, and the results of a study of the effect of different types of development are given. (Paragraphs 43–60, 65–83.)

17. The shape and spacing of buildings will materially affect the amount of light available, particularly at the higher densities of development commonly found in towns. Open planning is fundamental there, but its application depends on comprehensive developments of larger units of land than are customary at present. (Paragraphs 43–60, 65-83.)

18. Satisfactory artificial lighting of dwellings built for sale or to let should be ensured by a complete installation at the time of building, and this should include suitable fittings of prescribed performance, together with lamps or mantles of the correct sizes. (Paragraphs 209–212.)

19. The continued use of reasonable intensities with such installations will in many cases depend on the availability of low price gas or electricity supplies (Appendices VI and VII).

20. Attention is also called to the value of light decorations. (Paragraphs 14–15, 82–85, 156, 190, 199–202.)

21. *Recommendations for Schools.* Good lighting in schools is essential to the efficiency and comfort of both pupils and teachers, and since schools are buildings used compulsorily by the whole community, some form of control seems well justified and should be instituted for all schools, whether state-aided or otherwise. (Paragraph 219.)

22. The high incidence of eye defects in school children is a matter of grave concern. In the absence of an analysis of the relative importance of various possible causes for these defects, good lighting should be regarded as at least a necessary form of insurance. (Paragraphs 213–217.)

23. Recommendations are made in Part IV of this Report for minimum standards for both natural and artificial lighting. The natural lighting standards recommended involve departures from present practice in design. Possible solutions for single-storey schools are suggested. (Paragraphs 239–244.)

24. For multi-storey schools, the problem is difficult with classrooms of normal size and depth except as top floors. If, with the proposed reduction in numbers of children per class, somewhat shallower classrooms can be used for future schools, the problem would be much easier. In certain cases it may be necessary to rely upon artificial light to supplement daylight. (Paragraph 237.)

25. The artificial lighting of schools should be designed by qualified lighting engineers.

26. At certain times of the day there will be a need for supplementing daylight in the least well-lit parts of some classrooms, and in such cases it is recommended that the artificial lighting be designed for admixture with daylight, and that switching be arranged so that such light can be provided as required. Paragraph 247 refers to the automatic control of such switching. (Paragraphs 246–247.)

27. All possible steps should be taken to make improvements in existing schools in which the lighting is inadequate. Where adequate standards of daylight cannot be obtained special attention should be paid to the provision of supplementary artificial lighting. (Paragraphs 235–236.)

28. Decoration is a factor which not only affects the efficiency of lighting from the quantitative point of view, but is also important in providing comfortable visual conditions. (Paragraphs 260–264.)

29. Sunlight in classrooms is valuable and minimum standards are suggested. (Paragraphs 248–250.)

30. The provision of systematic maintenance of the artificial lighting, under properly qualified supervision, is important. Regular cleaning of windows is necessary for maintenance of good natural lighting. (Paragraph 260.)

C. C. PATERSON, *Chairman*
R. O. ACKERLEY
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APPENDIX I
TABLE OF FREQUENCIES OF DAYLIGHT ILLUMINATION THROUGHOUT THE YEAR

The following table, prepared for us by the National Physical Laboratory, gives, for three times of day, the number of days in the year when the illumination outdoors drops below certain intensities in representative localities,[1] one in the north and one in the south. The figures are averages from observations over several years.

TABLE A. I/1. FREQUENCIES OF DAYLIGHT ILLUMINATION THROUGHOUT THE YEAR

ILLUMINATION VALUE (foot-candles)	TEDDINGTON			EDINBURGH		
	NUMBER OF DAYS IN THE YEAR			NUMBER OF DAYS IN THE YEAR		
	9 a.m.	Noon	3 p.m.	9 a.m.	Noon	3 p.m.
Below 100 f.c.	6	3	14	19	1	12
,, 200 f.c.	21	9	35	47	4	37
,, 300 f.c.	36	16	53	72	11	63
,, 400 f.c.	54	25	77	88	17	81
,, 500 f.c.	67	33	94	104	26	94
,, 600 f.c.	83	43	110	118	33	109
,, 700 f.c.	97	55	121	130	44	120
,, 800 f.c.	111	68	135	139	53	132
,, 900 f.c.	125	80	146	149	66	141
,, 1000 f.c.	141	93	157	158	80	149
Above 1000 f.c.	224	272	208	207	285	216

For about a month in the year, the daylight is seen to drop below 500 f.c. even at mid-day, and a daylight factor of 1 per cent would then represent less than 5 f.c. The daylight drops below 250 f.c. for a fortnight or so, and the 1 per cent d.f. then represents 2·5 f.c. or less and so on; thus, those who are interested can obtain a connection between daylight factors and foot-candles, though we do not suggest that all designers need go to this trouble; it should be sufficient for the most part if they have some approximate idea of the intensities involved.

APPENDIX II. METHODS OF DESIGN FOR DAYLIGHTING

GENERAL

In the Report it is made clear that satisfactory daylighting is in the main dependent upon the penetration of a given daylight factor, and the area lighted to that value. These are both dependent, not only on the size of the window, but also on its shape, its location in the room, and the height of its centre above the working

[1] Teddington and Edinburgh

plane. Moreover both may be greatly affected by obstructions such as balconies, trees, and other buildings, which reduce the amount of sky visible through the window. It is apparent, with so many factors to be considered, that it is difficult, without a reliable guide, to predict whether a given window will give the illumination that is required. The real problem is most frequently the inverse of this, and is still more difficult. It is not to determine whether a given window will satisfy the requirements, but to ascertain what window is necessary to meet them. To allow a large factor of safety, so that the lighting is well above the level found satisfactory, is to evade the problem rather than to solve it.

It is clear from this summary that the methods to be used in solving these problems should not be too crude. We may safely leave the exceptional problem to those who have special experience in matters of this kind, but those of frequent occurrence fall within the ambit of this Report. It is essential that the methods to be used for dealing with these common problems should not be laborious, and the more readily they can be applied by all who have to use them the better. These considerations have been present in our minds in reviewing a number of methods which have been proposed for use in window design.

THE WALDRAM DIAGRAM

It is appropriate to mention, in the first place, a method due to P. J. and J. M. Waldram which has been used by its inventors and others for many years. In essence the method is graphical and makes use of a specially constructed reticule upon which an outline representing a window, either actual or próposed, is drawn.

At any point in a room the illumination due to a patch of visible sky naturally depends on the size of the patch, as measured by the solid angle it subtends at the point. Further, if the illumination considered is that on a horizontal plane, the value of a given patch of sky depends on its height above the horizon as well as on its size. For instance, it will be clear from Fig. 50 that the patch of sky at A contributes far more than an equal patch at B to the illumination of a horizontal plane P, because the light from B comes at such a low angle. It is a fairly simple matter to calculate the relative values of equal-sized patches at different angles of elevation; the value is, in fact, proportional to the sine of the angle.

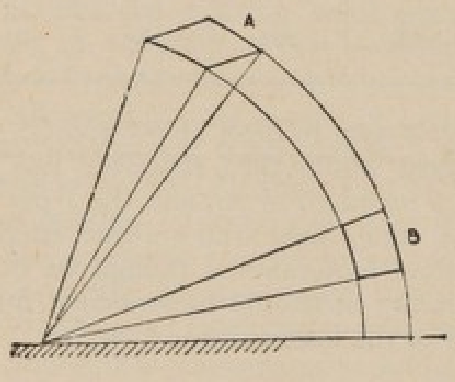


Fig. 50.

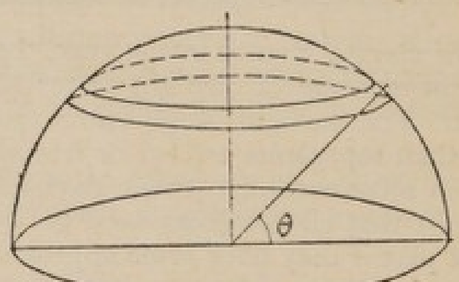


Fig. 51.

Next it is convenient to think of the hemisphere of sky divided into rings, or zones, of equal angular depth (see Fig. 51). Clearly, since the angle of elevation of all parts of the sky within a single zone is the same (if the zone is sufficiently shallow) the value of a given zone will be proportional to the sine of the angle of elevation of the centre line of the zone and to the area of the zone. Since this area is proportional to the cosine of the angle of elevation, it follows that zones of a given depth (*e.g.* one degree) have values proportional to sin θ cos θ where θ is the angle of elevation.

The Waldram diagram (Fig. 52) consists of a network of lines representing the hemisphere of sky divided into zones as just described. The horizontal length of each zone is made the same throughout, so in order to give each zone an area (on the diagram) proportional to its value as an illuminant, the depth of each zone is made proportional to sin θ cos θ. It follows that equal areas anywhere on the diagram then represent patches of sky making equal contributions to the illumination of a horizontal plane.

It will be seen that in order to find the daylight factor at any point in a room it is necessary (a) to trace on the diagram the outline of the patch of sky visible from the point, (b) to find, by planimeter or otherwise, the area of this patch, and (c) to express this area as a percentage of twice the area of the whole diagram if, as in the case of Fig. 52, the diagram represents one-half of the complete sky vault.

As an example, let it be required to calculate the daylight factor at a point 10 ft. from the centre-line of a window 5 ft. wide and 5 ft. high, the sill being a

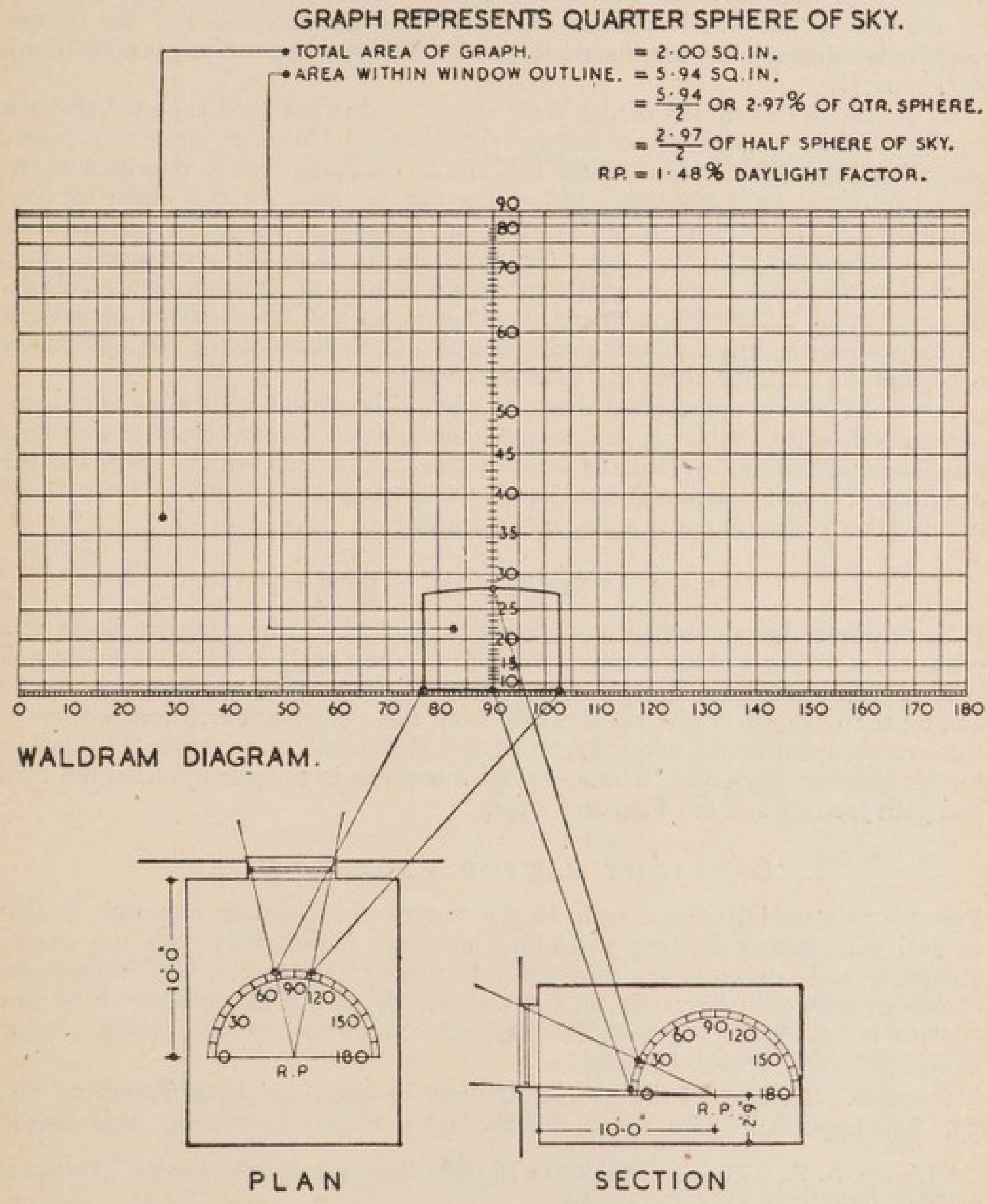


Fig. 52.

little above the working plane. The angular width of the window is 26 degrees (see Fig. 52) and the angles of elevation of (i) the centre of the window-head and (ii) of each top corner are respectively 28 and 27 degrees. The outline of the window on the Waldram diagram is therefore as shown in Fig. 52. The area within this outline is 2·97 per cent of the area of the whole diagram, so the daylight factor at the point considered due to an unglazed and unobstructed opening of the size and shape shown is 1·48 per cent.

It will be noticed that the line representing the top of the window on the diagram is not a horizontal straight line but droops gradually on each side. This is a natural consequence of the fact that the angle of elevation of the window head gradually becomes smaller as the distance from the centre increases. In the example above, for instance, the droop is 0·7° in going from the centre to the corner of the window. To facilitate the representation of horizontal lines a special Waldram diagram has been constructed in which "droop lines" are superimposed on the simple network shown in Fig. 52. The construction and use of this diagram is explained in Illumination Research Technical Paper No. 7 (2nd edition), Appendix II.

In the above description of the Waldram method it has been assumed that the window opening is unglazed, as well as unobstructed. However, when light passes through a sheet of clear glass there is a loss by reflection which increases as the obliquity of the light increases. Allowance can be made for this effect by constructing a Waldram diagram with a modified network in which the vertical scale of angles becomes more and more contracted as the sides are approached. (See *Journal of the Royal Institute of British Architects* for 17th October 1936, Vol. 43, p. 1072, where a description of the theory is given and the modified network is reproduced with droop lines superimposed.) The effect on the daylight factor is negligible except for unusually wide windows.[1]

It will be readily appreciated that this method is capable of dealing very comprehensively with problems of daylight illumination. Obstructions of any kind present no difficulties, so that the unusual case can be dealt with as readily as the ordinary. Nevertheless, for general use in the circumstances which we have chiefly in mind the method is not as suitable as some others.

THE SUMMATION METHOD

P. J. Waldram has described another method in which the daylight factor at a given point due to a small element of window in any position on the window wall is shown on a diagram. The daylight factor for any actual window is found by adding the daylight factors appropriate to all the elements which together cover the area occupied by the window. The method is described in full in *The Builder* for 1st October 1937, and an extension of it is given in the same journal for 23rd and 30th January and 6th February 1942.

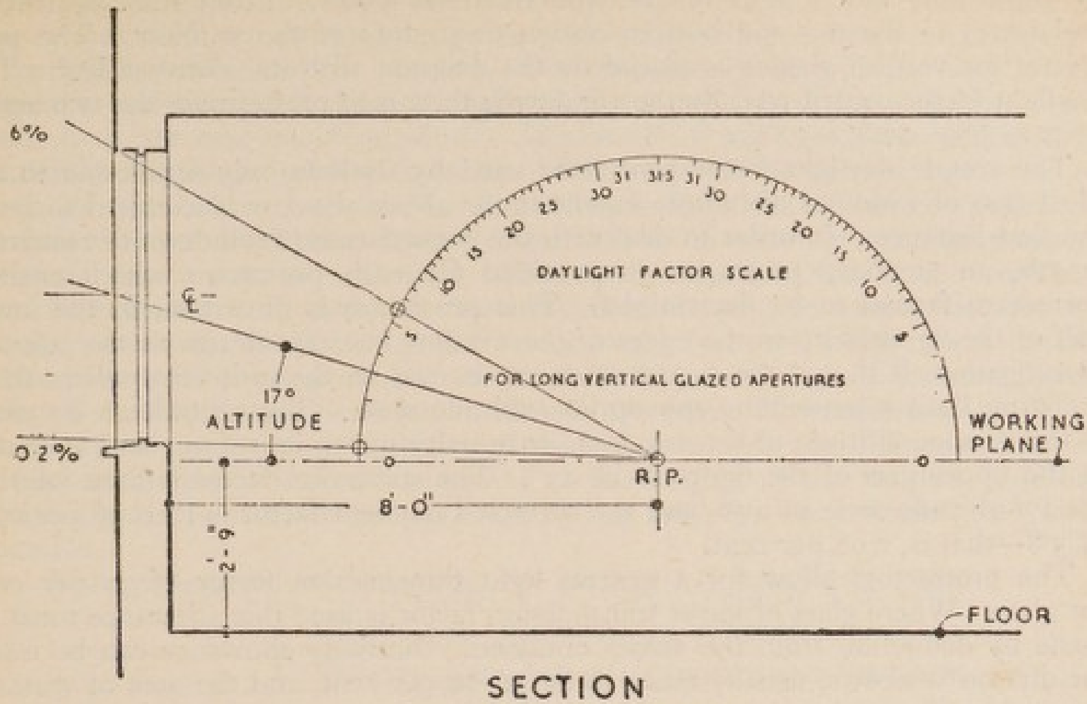
DAYLIGHT FACTOR PROTRACTORS

Protractors were introduced early in the war by the Building Research Station to deal with factory lighting problems,[2] and have found fairly wide use among architects and engineers for this and many other purposes. The instruments consist of celluloid protractors set out with a scale of daylight factors. Five protractors are available, one each for unglazed conditions, vertical glazing, glazing at 60°, 30°, and horizontal glazing.

Example. The use of the protractors may be explained by reference to Fig. 53. The upper half shows the section through a window in a room. It is desired

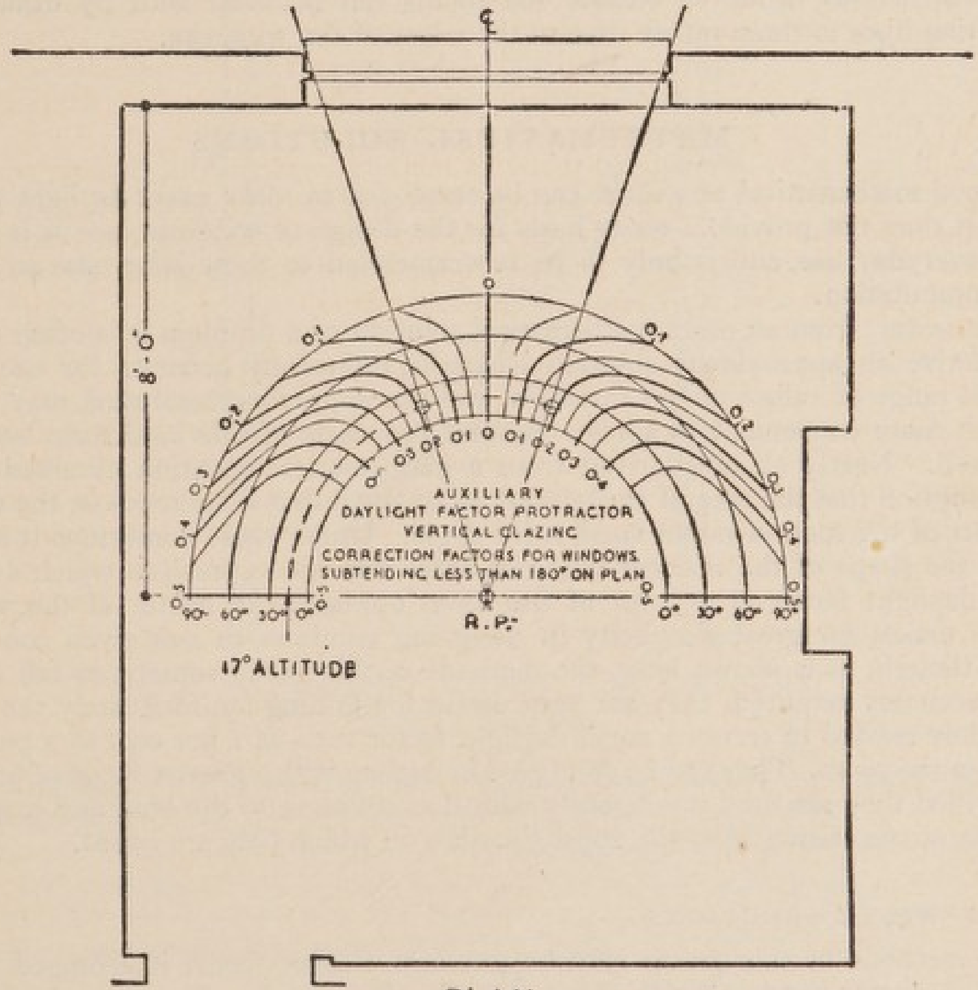
[1] Dufton, A. F., "The Computation of Daylight Factors in Factory Design," *Journal of Scientific Instruments*, 1940, 17 (9), 226.

[2] The protractors are available from the Building Research Station, Garston, Watford, price 10*s*. per set of 10 protractors, post free. The instruments are also sold separately.



SECTION

READING 6%-0.2% = 5.8%



PLAN

READING 0·18 – 0·18 = 0·36

DAYLIGHT FACTOR AT R.P. = 5·8 × 0·36 = 2·08%

Fig. 53.

to know how much light reaches the reference point. From R.P. sight-lines are drawn to the top and bottom obstructing edges of the window. The protractor for vertical glazing is placed on the diagram with its centre at R.P. The daylight factor contributed by the window is then read off between the two sight-lines as $6\%-0{\cdot}2\%=5{\cdot}8\%$.

The simple daylight-factor protractor used by itself is only applicable to the ideal case of windows of infinite extent as the above window is assumed to be in the first instance. In order to deal with the general case of windows of restricted length, an auxiliary protractor is provided for each protractor which enables correction factors to be determined. This procedure is illustrated in the lower half of the figure. From the edges of the window lines are drawn to the point of investigation, R.P. and the correction factor is read on the protractor where these radiating lines intersect the appropriate altitude scale. The altitude to be taken is the average altitude of the window, or the altitude to its centre, and is shown in the upper part of the figure to be 17°. The correction factor is then read on the 17° altitude scale as 0·36, and the corrected daylight factor is then 36 per cent of 5·8—that is, 2·08 per cent.

The protractors allow for a general light transmission factor of 90 per cent for glass. Where glass of lower transmission factor is used due allowance must be made by deduction from the values obtained. Similarly allowance can be made for dirt on windows, usually taken to be 10–20 per cent, and the area of window covered by glazing bars.

Obstructions inside or outside the rooms can be dealt with by drawing the limiting lines to these rather than to the edges of the windows.

MATHEMATICAL SOLUTIONS

Formal mathematical procedure can be employed to make exact daylight analyses but it does not provide a ready basis for the design of windows, nor is it suitable for everyday use, and is only to be recommended to those who take an interest in computation.

However, from an exact mathematical solution of a problem it is often possible to derive an approximate solution which is sufficiently accurate for use over a small range of values of the variables, and the approximate solution may be very much more convenient to apply. Several proposals of this kind have been considered. Nearly all are derived from a mathematical equation obtained on the assumption that the area of the window is so small that it subtends at the working points of the room a rather small solid angle. Under these conditions it is found that the shape of the window does not enter into the expression which evaluates the daylight factor at a point of the room opposite the centre of the window. This makes for great simplicity in designing windows to suit given conditions; and though, as is shown later, the methods of this group sometimes fall short of the accuracy required, they are very useful for finding approximately the size of window needed to secure a small daylight factor such as 1 per cent at a point well within the room. They can be employed in dealing with a greater range of problems provided they are used intelligently with due attention to the kind and magnitude of the errors arising from the approximation on which they are based.

UNIT WIDTH SOLUTIONS

The methods of this group may be put into elegant forms if arranged to give daylight factor per foot width of window of a given height. For example, J. W. T. Walsh has constructed an alignment chart (Fig. 54) for unobstructed windows with their sills in the working plane. To use the chart a straight-edge is placed to meet the scale on the left at the height of the window head and to cross the intermediate line at the point representing the distance from the window plane of the point P of the working plane where the daylight factor is to be ascertained. The intersection of the straight-edge with the scale on the right gives the daylight factor per foot width of the window. For example, if the window head is 5 ft. above the working plane the daylight factor for a point 11 ft. from the window is about 0·25 per cent per foot width. If a factor 1 per cent were required the window would have to be 4 ft. wide. This result is for an unglazed window. For a glazed window in which the obstruction by bars and allowance for dirt, etc. resulted in a loss of 40 per cent of the light this width would give a daylight factor of 0·6 per cent instead of 1 per cent, and to attain 1 per cent the width would have to be increased to 6 ft. 8 in. A chart of this kind could be constructed for any required ratio of glazed to unglazed values so that values could be read directly. It is obviously a very convenient form in which to present a great deal of information. If the chart were used for calculating the width of windows of which the lower parts were obstructed it would be necessary to take the difference between values of daylight factors corresponding to the heights of the window head and of the top of the obstruction. For use in this way the chart would need to be extended.

EXAMPLE: 1% required 11 ft. from Window 4 ft. wide
(0·25% per foot width of Window)
Window head being 5 ft. above working plane

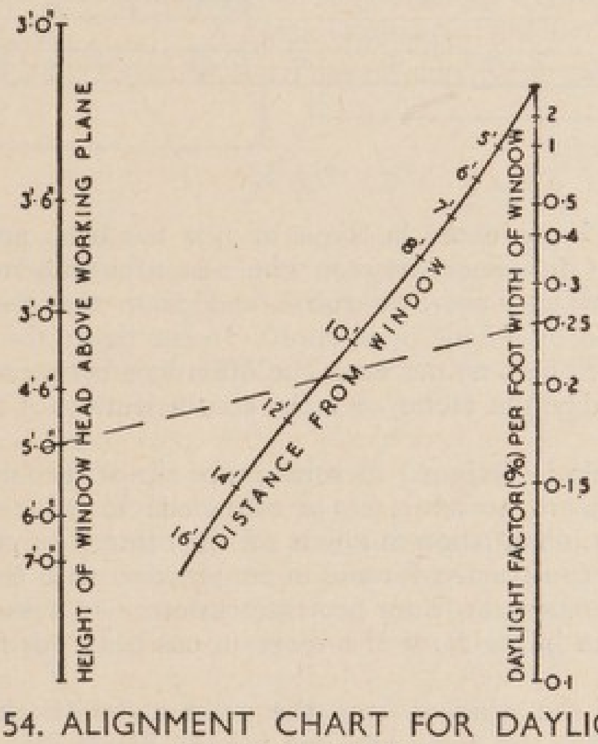


Fig. 54. ALIGNMENT CHART FOR DAYLIGHT CALCULATIONS

A. F. Dufton has proposed to deal with the same problem by constructing a specially graduated rule [1] for use with a scale drawing of a window.

In Fig. 55 if PA and PB are sight-lines to the top and bottom of the unobscured part of the window, and if Q and R are points on the working plane such that PAQ and PBR are right-angles, the daylight-factor-per-unit-width, opposite the centre of a narrow vertical unglazed window AB, is

$$\frac{1}{2\pi}\left(\frac{1}{PR}-\frac{1}{PQ}\right).$$

[1] Dufton, A. F., "The Window Scale," *Transactions of the Illuminating Engineering Society*, 1943, 8 (3), 61.

In the rule for glazed windows, 10 per cent has been deducted for the loss of light on passing through the glass. The daylight-factor-per-unit-width is then

$$\frac{1}{7\cdot0}\left(\frac{1}{PR}-\frac{1}{PQ}\right),$$

which is conveniently found from a drawing. This Committee has recommended an allowance of 20 per cent for loss of light due to glass and dirt.

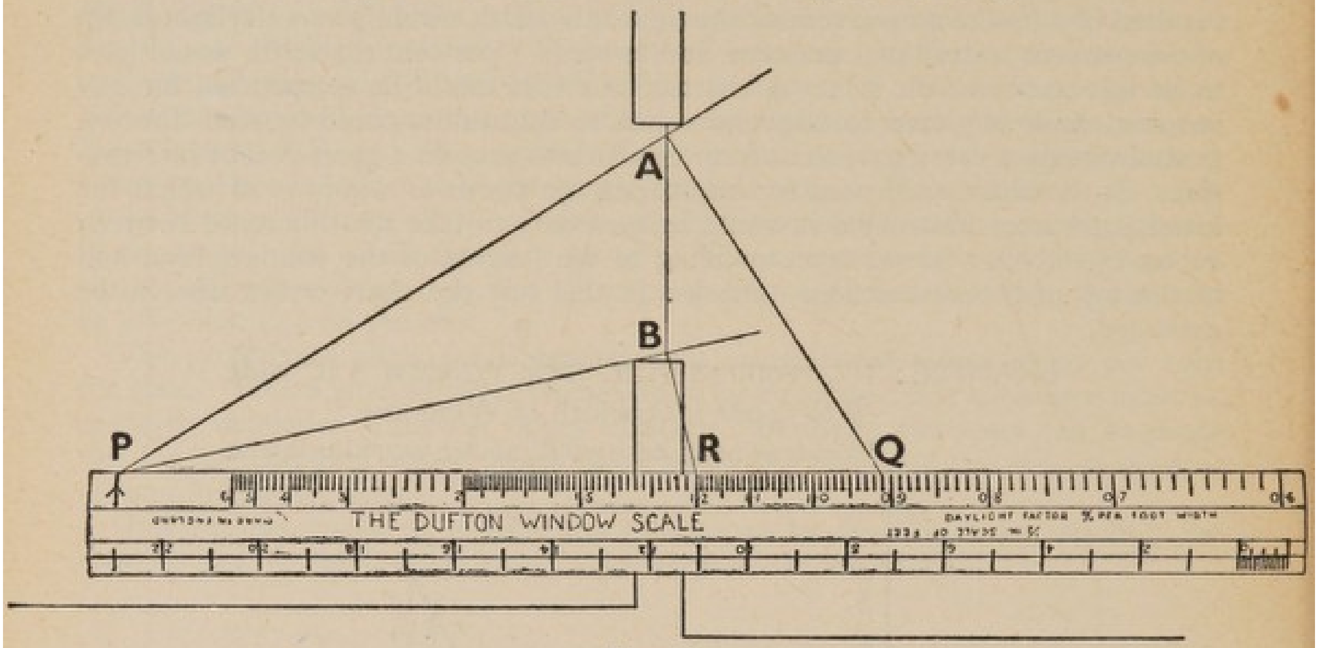


Fig. 55.

A wooden scale [1] graduated in terms of $1/7r$ has been prepared for use with $\frac{1}{2}$-in. details. The difference between two measurements made with this scale gives the daylight-factor-per-foot-width, and from this the width of window required is obtained by simple proportion. In the figure the daylight-factor-per-foot-width is seen to be 0·29 per cent, the difference between 1·20 and 0·91; and to provide at P a daylight factor of 1 per cent a window 3 ft. 6 in. wide would be required.

The window scale is designed to solve quite simple problems in fenestration. Its sphere of usefulness, however, can be extended: for wide windows and for the investigation of the illumination at points off the centre-line of a window auxiliary protractors can be constructed for use in conjunction with the scale much in the same way as for the daylight-factor protractors described above.

A similar solution in the form of a diagram has been put forward by J. W. T. Walsh (Fig. 56).

The distance of the window from the point at which the daylight factor is desired is taken along the horizontal line marked Table Plane and a vertical line is drawn to represent the window wall. The position of the point representing the window-head then gives, by interpolation between the figures marked on the nearest semi-circles, a certain value of daylight factor. (What this value really represents is explained in the next section.)

The sloping lines are marked with angles of obstruction, and the point where the line representing the appropriate angle of obstruction cuts the vertical line representing the window wall gives, in the same way, a second value of daylight factor *larger than the first*. The daylight-factor-per-foot-width of window is the difference between these two values. If the window is unobstructed the larger of the two values is that corresponding to the lowest point of the window wall (*i.e.* the point where the obstruction line for 0° would cut it).

[1] Available from Messrs. C. F. Casella, London.

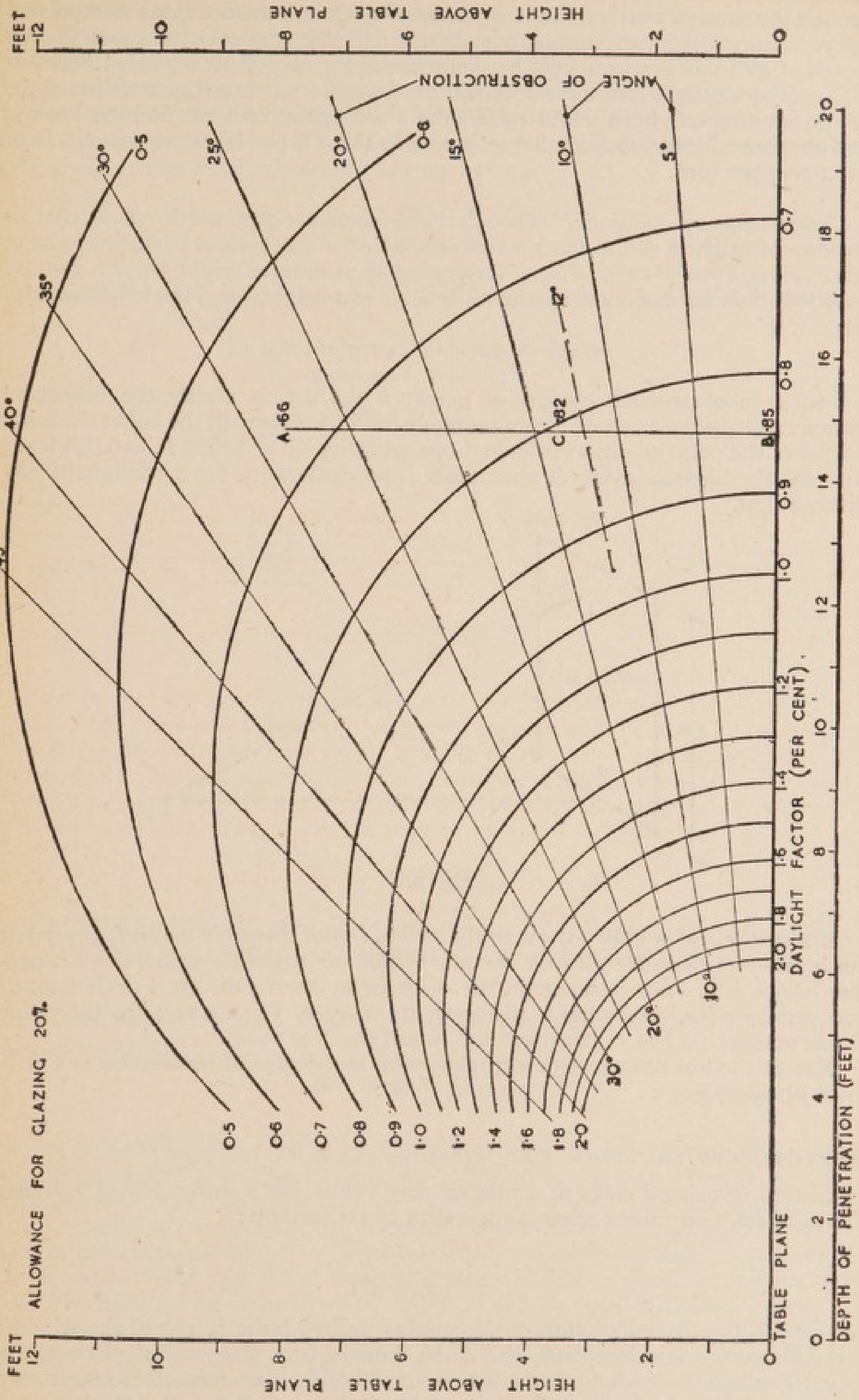

HEIGHT ABOVE TABLE PLANE
FEET
ANGLE OF OBSTRUCTION
ALLOWANCE FOR GLAZING 20%
DAYLIGHT FACTOR (PER CENT)
DEPTH OF PENETRATION (FEET)
TABLE PLANE
A ·66
B ·85
C ·82
12°

Fig. 56.

Example. If the point is distant 15 ft. from a window 8 ft. high the line representing the window wall is AB. A represents the window-head and the interpolated figure obtained from the semi-circles is 0·66. If the angle of obstruction is estimated at 12°, this is represented by point C and the second interpolated figure is 0·82. The daylight-factor-per-foot-width of window is therefore 0·16 per cent. If the window had been unobstructed the obstruction point would have been B and the second interpolated value 0·85, so that the d.f.-per-foot-width would have been 0·19 per cent.

Construction of Diagram. The daylight-factor-per-foot-width of a narrow window of height h at a distance x from the point of observation (assumed to be at sill level) is $h^2/2x(x^2+h^2)$. Hence for a window of infinite height the d.f. is $1/2x$. It follows that for a window in which the sill is at a height h and the height infinite the d.f. is

$$(1/2x)-h^2/2x(x^2+h^2)=x/2(x^2+h^2).$$

For an unobstructed window of height h the d.f. is clearly the difference between the daylight factors for an infinitely high window with the sill at the same height as the point of observation and one with the sill at height h, and this leads to a simple diagram giving at once the d.f.-per-foot-width for a window of any given height.

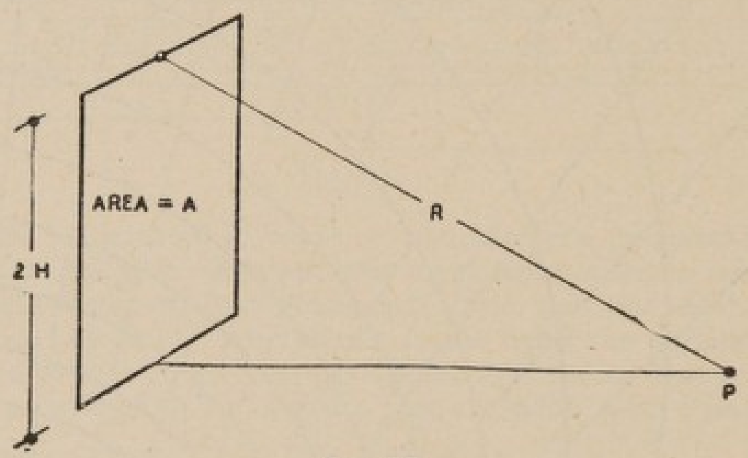


Fig. 57.

If a semi-circle is drawn through the point X with diameter $a=1/2f$, any point on it will represent the sill of a window of infinite height for which the d.f.-per-foot-width is f. For instance, in the diagram as drawn, the semi-circle marked 1·0 per cent (*i.e.*=0·01) has a diameter, to scale, of 1/0·02=15·9 ft., the semi-circle marked 2·0 has a diameter equal to half this and so on.

The method of dealing with a window with any degree of obstruction is a self-evident extension.

APPROXIMATE SOLUTION FOR WINDOW AREAS

Instead of using a chart or a rule we may clearly use a mathematical formula. Thus Walsh's alignment chart is equivalent to the formula:

$$\frac{2\pi f}{w}=\frac{h^2}{x(x^2+h^2)}$$

where f is the daylight factor, w the window width, h the height of the window head above the working plane, and x the distance from the window plane of the point P where the daylight factor is to be calculated. This formula is satisfactory when the value of w in the real window is small, but as w increases it tends to give too great a value of f—an error in the less tolerable direction. This illustrates the limited range of applicability of methods which do not take the shape of the window into account. We can modify the formula to make it suitable for use for conditions other than small values of w. If we assume that P is at a considerable distance from the window, so that f is small, we obtain an expression which errs in the more acceptable direction by replacing the solitary x in the denominator by R, where R is the distance of the window-head from P, so that $x^2+h^2=R^2$. The modified formula is then

$$\frac{2\pi f}{w}=\frac{h^2}{R^3},$$

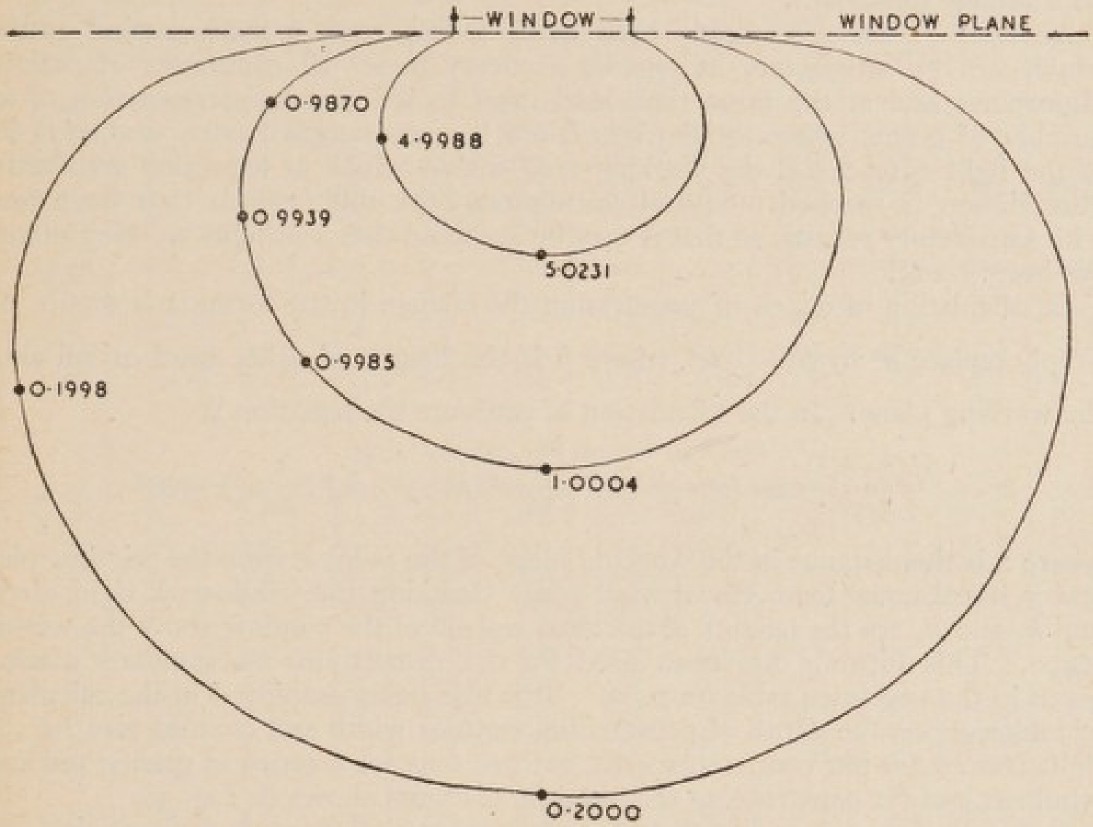


Fig. 58. CONTOURS OF 5%, 1% AND 0·2% DAYLIGHT FACTORS FOR A SQUARE WINDOW WITH SILL IN WORKING PLANE

and from this we obtain a direct formula for the area of window A required to yield the daylight factor f,

$$A=\frac{kfR^3}{H},$$

where H is the height of the *centre* of the window above the working plane. The quantities occurring in this formula are indicated in Fig. 57. For an unglazed window $k=\pi$, and this value may be increased to allow for the increased overall area A needed to compensate for the presence of window bars and the loss of light due to reflection and dirt. For metal-framed windows 5·2 is a suitable value for k. It should be noted that if this formula is used for finding window areas for large daylight factors, that is for points P where R will be large compared with x, the area obtained may be considerably greater than is in fact necessary. If this restriction is recognized this expression for A will be found satisfactory. In the form given it may be employed when obstructions are present. In this event, as shown in Fig. 57, A is the area of window through which a clear view of the sky can be seen from P and H is the height above the working plane of the centre of the area A. In view of the influence of ceiling height on cost on the one hand and on effective lighting on the other, it is fortunate that reasonable results can be obtained from a formula into which the position of P only enters through its distance from the window-head.

A MORE EXACT MATHEMATICAL SOLUTION

Our experience with any one of the approximate methods just described has shown that they do not fully meet our needs. Apart from the limited range over which they are of good accuracy they have the defect of only giving the depth of penetration; in practice the area included in the daylight-factor contour is at least equally important.

An attempt has accordingly been made to construct a mathematical method which will be satisfactory as regards accuracy under all conditions of practical importance and at the same time lend itself to the direct determination of any number of points where the daylight factor has any assigned value, and so to that of the light spread, *i.e.* the working area within which at least that standard of illumination is reached. Several calculations with this formula have been made with satisfactory results, so that it may be accepted that a suitable working method has been found.

In calculation of depth of penetration the change in the formula is small. We simply replace h^2 by $h^2+\frac{1}{12}w^2$, where h is the height of either head or sill above the working plane. In the calculation of contours the equation is

$$\frac{(h_1^2-h_2^2)}{2\pi f}wx=(x^2+y^2+h_1^2+\frac{1}{12}w^2)(x^2+y^2+h_2^2+\frac{1}{12}w^2)-y^2w^2$$

where x is the distance in the working plane of the point P from the window plane and y its distance from the vertical plane bisecting the window at right angles, and h_1 and h_2 are the heights of the head and sill of the window above the working plane. This formula has been used for the calculations on standard windows given in the specimen table on p. 89. It is also being employed in the calculation of tables giving the depth of penetration, contour width and contour area for daylight factors 2·0 per cent, 1 per cent, 0·5 per cent for a series of graded unbarred windows and for constructing the example contours shown in Fig. 58.

It has been noted earlier that the exact theoretical formula is much less convenient to use than the approximations considered here. Nevertheless it has been desirable to construct Tables by this formula which can be used both to check the accuracy of conclusions reached by approximate methods and to facilitate the more difficult type of problem which we have not thought it necessary to discuss at length in this Report. We hope these tables are being published with an explanation of their use. For a description of this formula see "Note on Window Calculations," T. Smith, *Transactions of the Illuminating Engineering Society* (*London*), Vol. VIII, No. 6, June 1943.

Table A. II/1.

Graded Daylight-Factor Tables for Unbarred Windows.
0·5 per cent Daylight Factor. 15° Obstruction

Height of Window Head above Working Plane	Width of Window 3′ 0″	3′ 6″	4′ 0″	4′ 6″	5′ 0″	5′ 6″	6′ 0″	6′ 6″	7′ 0″	7′ 6″	8′ 0″
	Depth of Penetration in Feet										
6′ 0″	11·4	11·9	12·4	12·8	13·1	13·5	13·8	14·0	14·3	14·5	14·7
5′ 9″	11·0	11·5	12·0	12·4	12·7	13·1	13·3	13·6	13·8	14·0	14·2
5′ 6″	10·7	11·2	11·6	12·0	12·3	12·6	12·9	13·1	13·4	13·6	13·7
5′ 3″	10·4	10·8	11·2	11·6	11·9	12·2	12·4	12·7	12·9	13·1	13·2
5′ 0″	10·0	10·4	10·8	11·2	11·5	11·7	12·0	12·2	12·4	12·6	12·7
4′ 9″	9·7	10·1	10·4	10·8	11·0	11·3	11·5	11·7	11·9	12·1	12·2
4′ 6″	9·3	9·7	10·0	10·3	10·6	10·8	11·0	11·2	11·4	11·6	11·7
4′ 3″	8·9	9·3	9·6	9·9	10·1	10·4	10·6	10·7	10·9	11·1	11·2
4′ 0″	8·5	8·9	9·2	9·4	9·7	9·9	10·1	10·2	10·4	10·5	10·6
3′ 9″	8·1	8·5	8·7	9·0	9·2	9·4	9·6	9·7	9·8	10·0	10·1
3′ 6″	7·7	8·0	8·3	8·5	8·7	8·9	9·0	9·2	9·3	9·4	9·5
3′ 3″	7·3	7·6	7·8	8·0	8·2	8·4	8·5	8·6	8·8	8·9	9·0
3′ 0″	6·9	7·1	7·4	7·5	7·7	7·9	8·0	8·1	8·2	8·3	8·4
2′ 9″	6·4	6·7	6·9	7·0	7·2	7·3	7·4	7·5	7·6	7·7	7·8
2′ 6″	6·0	6·2	6·4	6·5	6·6	6·8	6·9	7·0	7·0	7·1	7·1
	Half-breadth of Contour in Feet										
6′ 0″	8·5	9·1	9·6	10·0	10·5	10·9	11·3	11·7	12·0	12·4	12·8
5′ 9″	8·3	8·8	9·3	9·8	10·2	10·7	11·0	11·4	11·8	12·1	12·5
5′ 6″	8·1	8·6	9·1	9·5	10·0	10·5	10·7	11·1	11·5	11·8	12·2
5′ 3″	7·9	8·4	8·9	9·3	9·7	10·1	10·5	10·8	11·2	11·5	11·9
5′ 0″	7·6	8·1	8·6	9·0	9·4	9·8	10·2	10·5	10·9	11·2	11·6
4′ 9″	7·4	7·9	8·3	8·8	9·1	9·5	9·9	10·2	10·6	10·9	11·2
4′ 6″	7·2	7·6	8·1	8·5	8·9	9·2	9·6	9·9	10·2	10·6	10·9
4′ 3″	6·9	7·4	7·8	8·2	8·6	8·9	9·3	9·6	9·9	10·3	10·6
4′ 0″	6·7	7·1	7·5	7·9	8·3	8·6	9·0	9·3	9·6	9·9	10·3
3′ 9″	6·4	6·9	7·3	7·6	8·0	8·3	8·7	9·0	9·3	9·6	9·9
3′ 6″	6·2	6·6	7·0	7·3	7·7	8·0	8·3	8·7	9·0	9·3	9·6
3′ 3″	5·9	6·3	6·7	7·0	7·4	7·7	8·0	8·3	8·7	9·0	9·3
3′ 0″	5·7	6·0	6·4	6·7	7·1	7·4	7·7	8·0	8·3	8·7	9·0
2′ 9″	5·4	5·7	6·1	6·4	6·7	7·1	7·4	7·7	8·0	8·3	8·7
2′ 6″	5·1	5·4	5·8	6·1	6·4	6·7	7·1	7·4	7·7	8·0	8·4
	Area of Contour in Square Feet										
6′ 0″	152	170	186	202	217	231	244	258	271	283	295
5′ 9″	144	160	176	191	204	218	231	243	255	267	279
5′ 6″	136	151	166	180	193	206	217	229	241	252	263
5′ 3″	128	142	156	169	181	193	204	215	226	237	247
5′ 0″	120	133	146	158	170	181	191	202	212	222	231
4′ 9″	112	125	137	148	158	169	179	188	198	207	216
4′ 6″	105	116	127	137	147	157	166	175	184	192	201
4′ 3″	97	108	118	127	136	146	154	162	170	178	186
4′ 0″	90	99	109	117	126	134	142	149	157	164	172
3′ 9″	82	91	100	108	115	123	130	137	144	151	158
3′ 6″	75	83	91	98	105	112	119	125	131	138	144
3′ 3″	68	75	82	89	95	101	107	113	119	125	131
3′ 0″	61	68	74	80	85	91	97	102	107	113	118
2′ 9″	54	60	66	71	76	81	86	91	96	101	106
2′ 6″	48	53	58	62	67	72	76	80	85	89	94

APPENDIX III. METHODS OF SUNLIGHTING ANALYSIS

Several methods of sunlight analysis have been put forward in the past, and have been described in R.I.B.A. Report on the Orientation of Buildings, 1933. In addition, Burnett has recently suggested another method. Of all the methods we feel that the ones most useful to designers are the new Burnett diagrams, which are used with drawings, and the Heliodon, which is used with models. We have therefore decided to include descriptions of these two methods in our Report.

BURNETT DIAGRAMS

There are two diagrams, one for use on plan and the other on section.

The first diagram (Fig. 59) is for use with plans and consists of parts of circles each representing the centre day (usually the 15th) of each month, the hours of

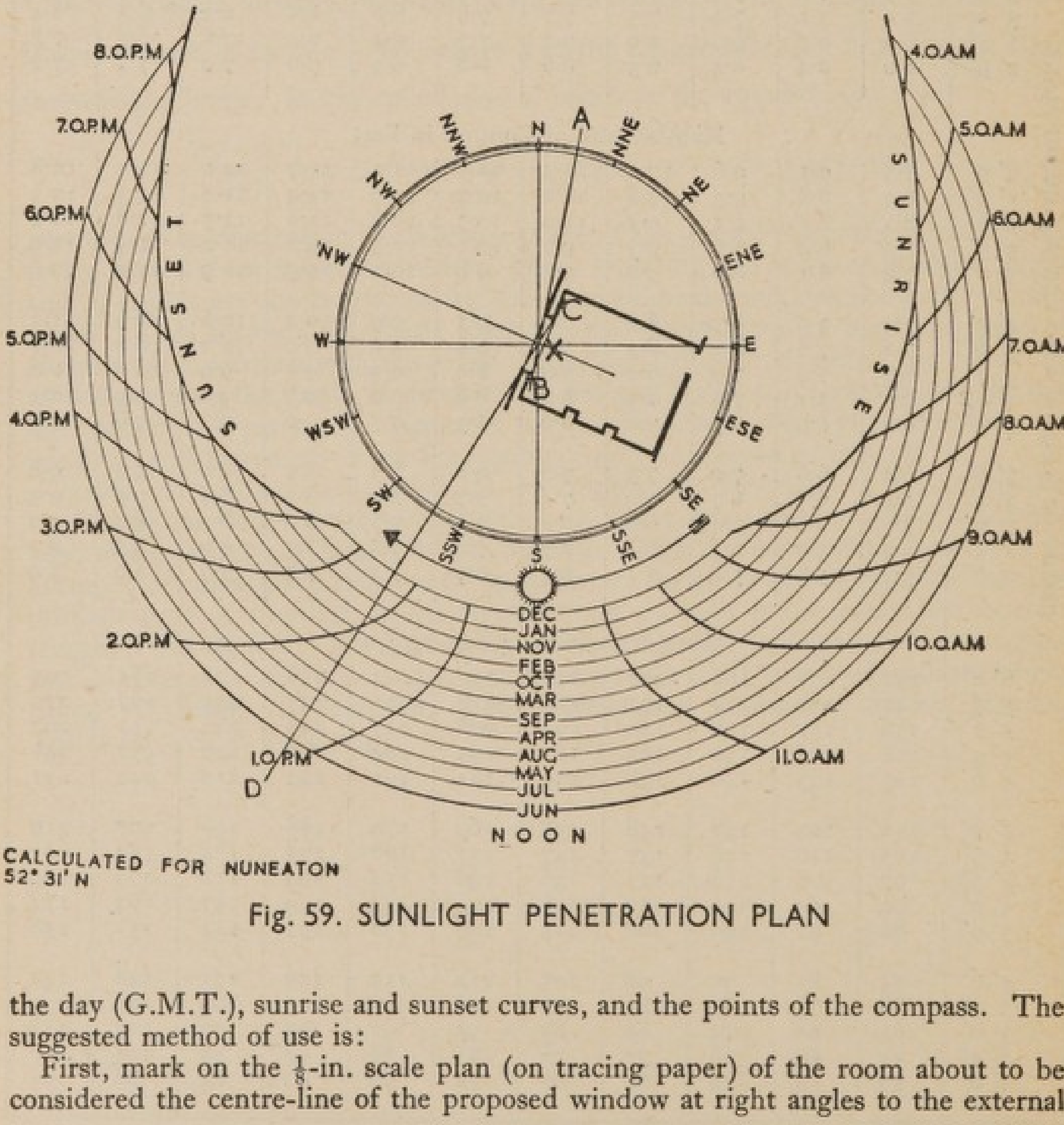


Fig. 59. SUNLIGHT PENETRATION PLAN

the day (G.M.T.), sunrise and sunset curves, and the points of the compass. The suggested method of use is:

First, mark on the $\frac{1}{8}$-in. scale plan (on tracing paper) of the room about to be considered the centre-line of the proposed window at right angles to the external

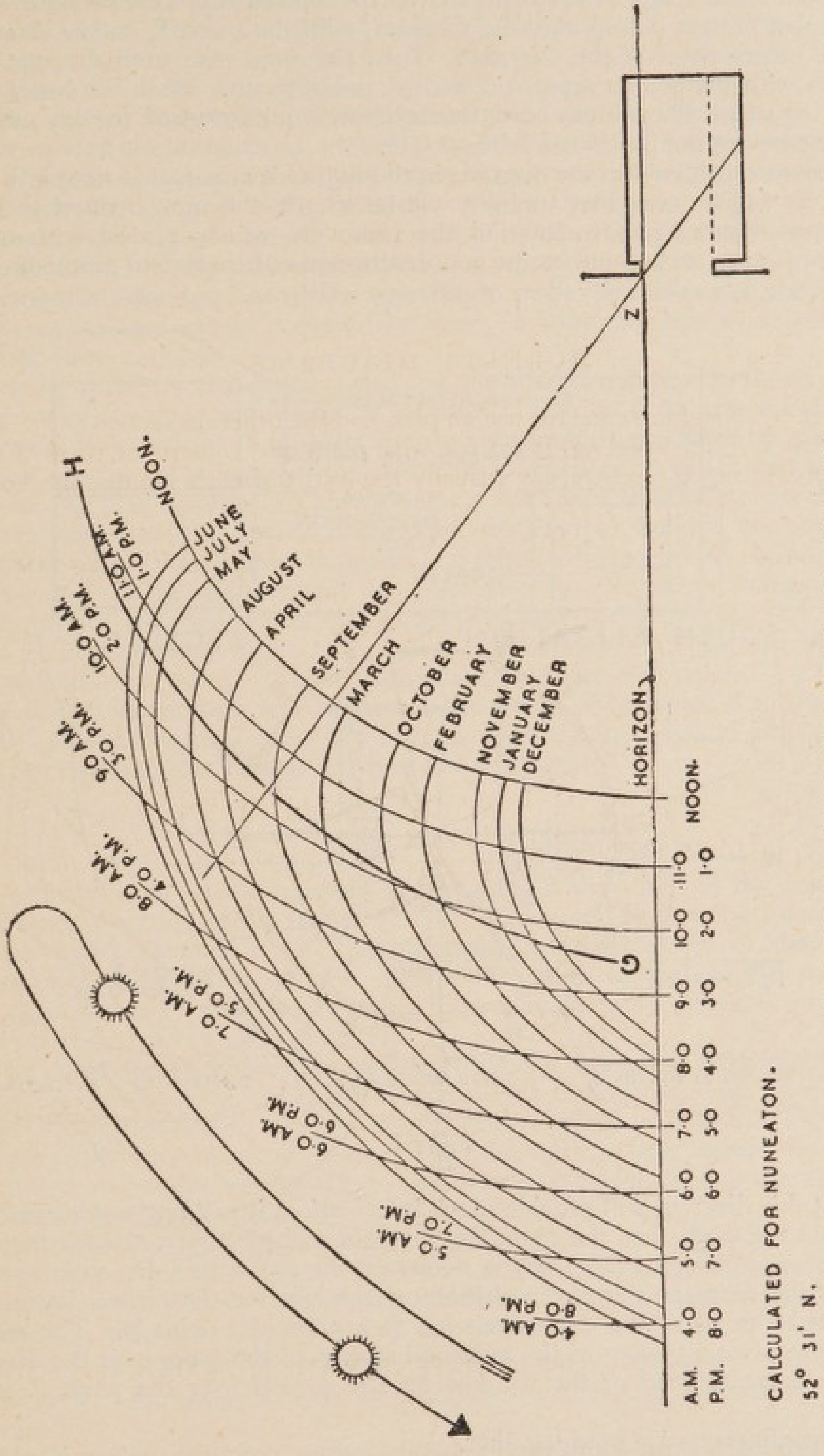


Fig. 60. SUNLIGHT PENETRATION SECTION

face and produce it as an aspect line. Mark on this line the proposed aspect of the room.

Secondly, mark on the limit lines imposed by the thickness of the external wall, produced to some length, as AB and CD, in the manner indicated on the Figure.

This plan is then placed over the diagram, with the point X on the room plan over the centre point of the diagram. Turn the room plan until the aspect line coincides with the proper aspect marked on the diagram. Then the hours of the day during which the sun can enter that window can be read off for any month of the year between the limit lines AB and CD.

The room considered in the example in the Figure is assumed to have a W.N.W. aspect. It will be seen that sunlight will be admitted from shortly after 2 p.m. in December, and 1 p.m. in June, until sunset. By moving the room plan round over the diagram always with point X over the centre, the effect of different aspects can be studied, and also the effect of different widths and positions of the window.

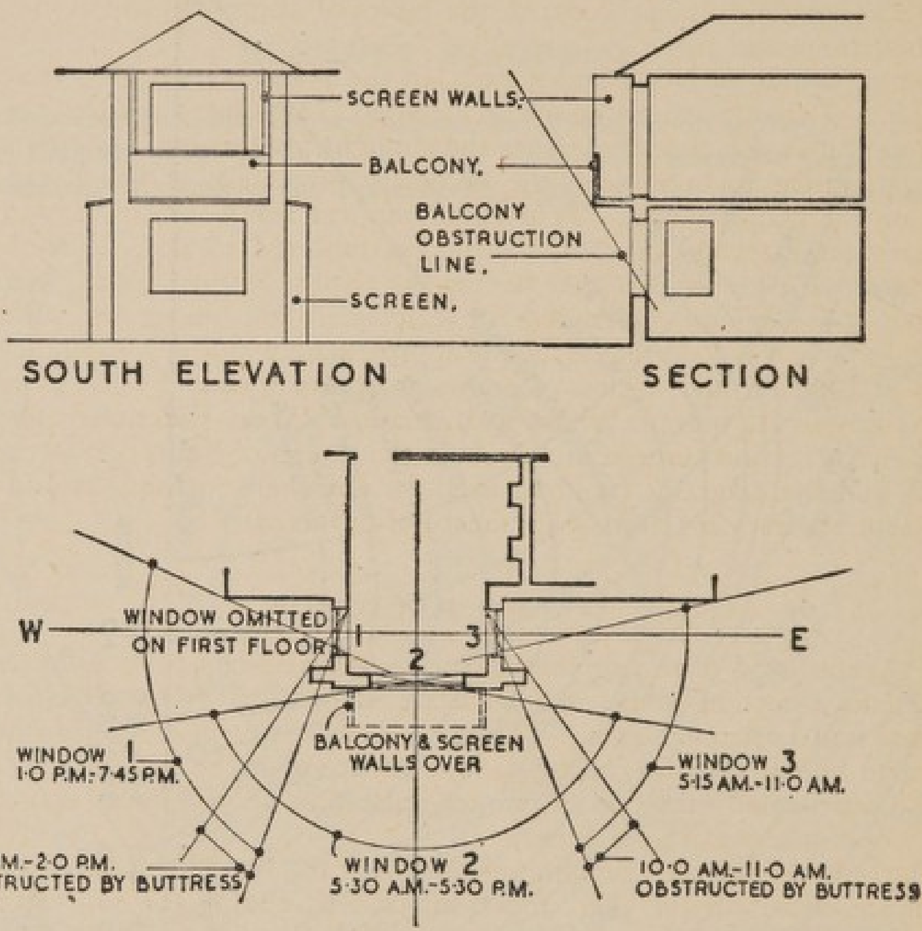


Fig. 61.

Whilst this diagram will provide much information, it will not provide information about the depth into the room that sunlight will penetrate, and for that purpose a second diagram (Fig. 60) is necessary for use with $\frac{1}{8}$-in. scale sections. This section diagram shows the altitude of the sun for the centre day of each month at all times of the day in relation to a particular point Z. The method of use is to place a tracing of the proposed section of the room over the diagram, with the external head of the window on the section over the point Z in the diagram.

The two diagrams are used together.

First, place the room plan over the plan diagram and then place the room section over the section diagram. Read off from the plan diagram the times indicated by the limit lines AB and CD, and mark these times on the section diagram, as at EF and GH on the figure. (In the example shown EF is after sunset.) Then the sunlight available for admission to the room for the particular aspect chosen is represented by the month and afternoon time curves between the lines EF and GH, and can then be projected down to the floor or table level of the room section, giving the actual depth of sunlight penetration into the room at any time, as shown for August, 3 p.m.

By means of these two diagrams normal problems of insolation can be solved quickly, easily, and with sufficient accuracy for architectural purposes. Also, problems which sometimes arise relating to the exclusion of sunlight can be solved.

A typical example of the use of the two diagrams for the approximate solution of an everyday problem for architects is shown in Fig. 61, which shows plan, section, and elevation of a living room, with bedroom over, in a small house having a south aspect. The problem is to design a projecting bay in a manner that will allow all available sun to enter the living room from early morning to late evening all the year round except between the hours of approximately 10 a.m. to 2 p.m. in May, June, and July.

Testing windows No. 1 and 3 first, on the plan diagram, it is found that only one hour of the undesired period is included. As a hood reduces the daylight in the room, it is decided to obstruct the sunlight for this one hour by vertical projections similar to buttresses, the necessary projection of which can be seen at once on the plan diagram. This leaves only the south window 2, and the section diagram indicates the line of obstruction required to exclude sunlight for the necessary period, and a balcony having the required projection is then added.

The two diagrams illustrated are calculated for Nuneaton, latitude 52° 31′ north, which was selected as being approximately the geographic centre of the mass of England and Wales. London is approximately 1° less and Manchester approximately 1° more. Whilst mathematically these differences of 1° are substantial, for the purposes of architects in the design of buildings they are relatively small, and the diagrams could be used for anywhere in England and Wales with sufficient accuracy for normal architectural purposes.

THE HELIODON

The general form of the apparatus can be seen in Plate 6.[1] A flat board, which represents a portion of the earth's surface, is mounted so as to be rotatable about vertical and horizontal axes. The horizontal axis enables the inclination of the board to be adjusted for latitude: movement about the vertical axis corresponds to the earth's daily rotation, a pointer indicating upon a horizontal circular scale hours and minutes of solar time.

The only adjustment entailing movement of the lamp, which represents the sun, is for the season of the year, and is effected by sliding the lamp upon a vertical scale of solar declination which is conveniently divided in months. In setting up the apparatus care must be taken to place the scale at the correct distance from the board and to ensure that the equinox mark on the scale is at the same height as the centre of the board.

In rooms of moderate size a vertical scale 7 ft. 6 in. long has been found suitable; this brings the centre of the board to the convenient height of 3 ft. 9 in. from the floor. Where space is not restricted it is an advantage to employ a larger apparatus; this minimizes the error due to the finite distance of the lamp from the model or, alternatively, permits the examination of larger models.

Example. An example with the Heliodon will illustrate several points about its use.

The architect of a city in the Midlands submitted to the Building Research Station a scheme for the reconstruction of the shopping area of the city, which

[1] The Heliodon is obtainable from Messrs. G. Cussons Ltd., Manchester.

has been destroyed by enemy action. The design consisted of a space approximately 200 ft. by 700 ft., divided into three bays at successively higher levels and enclosed by buildings five to six storeys high on all sides. The lower parts of the buildings were for shops, and the upper parts for offices. The central area was to be planted and used by pedestrians only, with parking space outside the scheme on the north side. In the central bay it was proposed to build a crèche where shopping mothers could leave their children. It was appreciated by the designer that sunlight is important in certain types of shopping area, and he desired to know what conditions would be like in winter in this scheme.

The main axis of the arrangement lies E. and W. so that maximum shadowing is developed by the enclosing buildings. Plate 7A shows the scheme under conditions of early and late winter lighting. At extreme mid-winter the full area of enclosed space would be shadowed at all times of day. A number of alternative modifications were tried, and finally it was thought best to break open the south block by turning it into two independent blocks at right angles to the main axis with the line of shops maintaining the original enclosure. The effect of this rearrangement is shown in Plate 7B, and it is evident at once that the central area is now generously swept by sunlight.

In addition the office accommodation is improved by facing East and West rather than North and South, thus sharing out the available sunshine.

The Heliodon is seen to provide a useful means of examining schemes of this kind and is a valuable adjunct to the town-planner's equipment.

APPENDIX IV. THE INFLUENCE OF WINDOW SHAPE IN NATURAL ILLUMINATION

We are dealing with unobstructed windows, and it may be assumed that the sill is in the working plane. Let w denote the width of the window and h the height of its head above the working plane. The area A of the window is then equal to hw, and if this area is unglazed it is all effective in transmitting light. It is convenient here always to mean by A this extreme area, and to take account of the light inevitably lost in real windows by applying a suitable coefficient to the daylight factor. We obtain a value of the right order if we suppose that a real window transmits half as much light as an unglazed window having the same value of A. This permits us to say that the quantity employed here to denote the illumination level has the value of 1/8 for a daylight factor of 1 per cent, 1/4 for 2 per cent, and so on in proportion.

At the levels of practical importance the illumination at a point (x, y) of the working plane (x is the distance from the plane of the window and y that from the vertical plane bisecting the window at right angles) is given with ample accuracy by the equation:

$$h^2wx=\phi[(x^2+y^2+\tfrac{1}{12}w^2)(x^2+y^2+\tfrac{1}{12}w^2+h^2)-y^2w^2].$$

To determine the penetration d we have to put $x=d$, $y=0$. We can also simplify the equation by noting that $\frac{1}{12}w^2$ is usually negligible in comparison with d^2. On dividing throughout by hd we then have

$$A=\phi d^2\left[\frac{d}{h}+\frac{h}{d}\right]$$

as an equation giving the area A of the window needed to secure the depth of penetration d at illumination ϕ. The minimum value of A is $2\phi d^2$, but this is only obtained when the window height is substantially equal to d. For a 1 per cent daylight factor the most efficient window is of the dimensions d high and $\frac{1}{4}d$ wide, and for a 2 per cent factor the dimensions are d high and $\frac{1}{2}d$ wide. These are decidedly high and not wide windows.

The changes in area required as the window shape is altered are not negligible. The most violent changes occur if the width of window is reduced appreciably below the optimum value. If windows of half this width are taken the value of

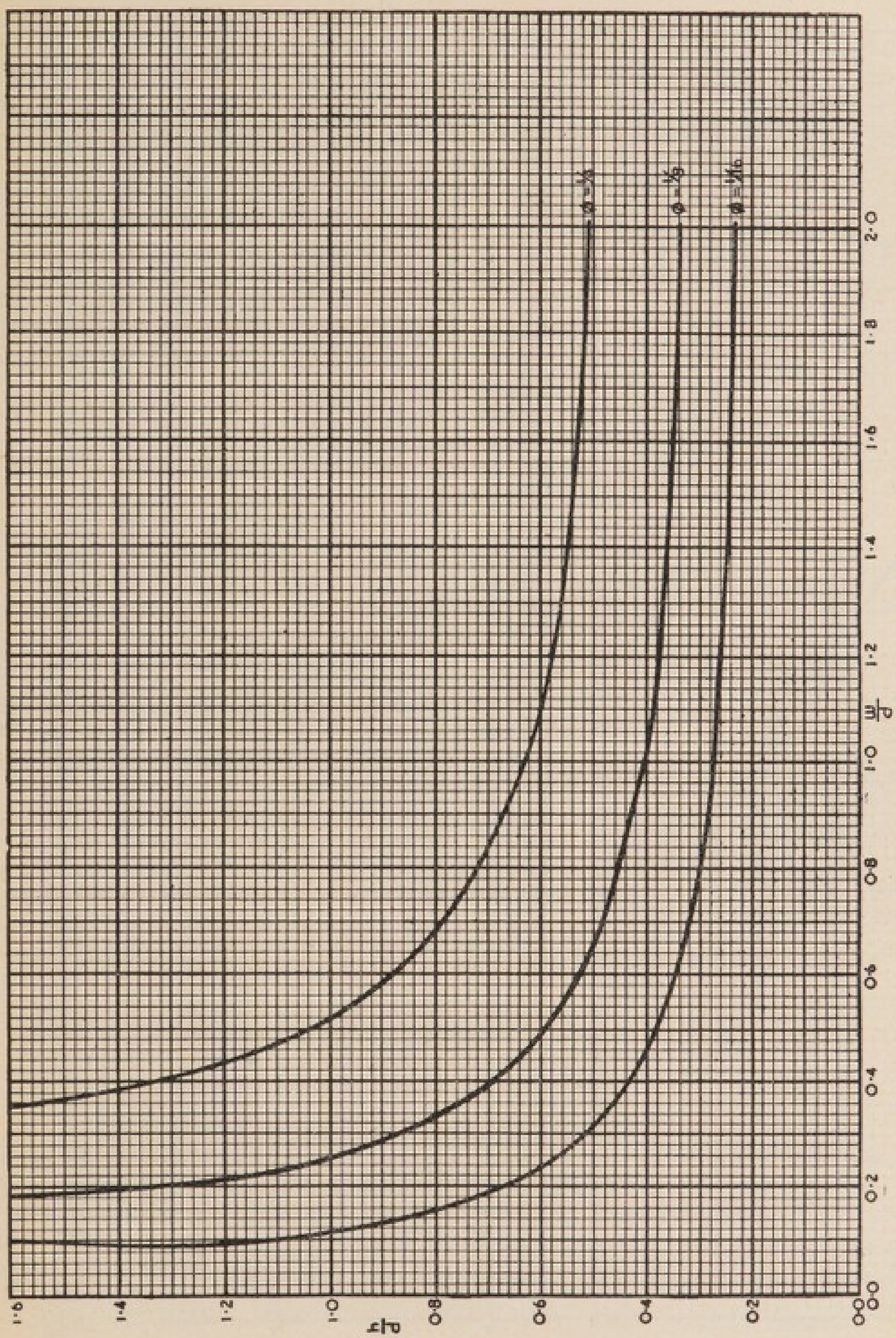


Fig. 62.

h, and therefore also that of A, become infinitely great. On the other side of the best shape the changes are more moderate. If windows half the height of the most efficient shape are taken the width must be increased two and a half times, *i.e.* the area must be increased by 25 per cent. For a 1 per cent daylight factor the dimensions would then be $\frac{1}{2}d$ high and d wide, a shape not very far from square, and for a 2 per cent daylight factor $\frac{1}{2}d$ and $\frac{5}{4}d$ wide, a distinctly long window. To obtain an approximately square shape for a daylight factor of 0·5

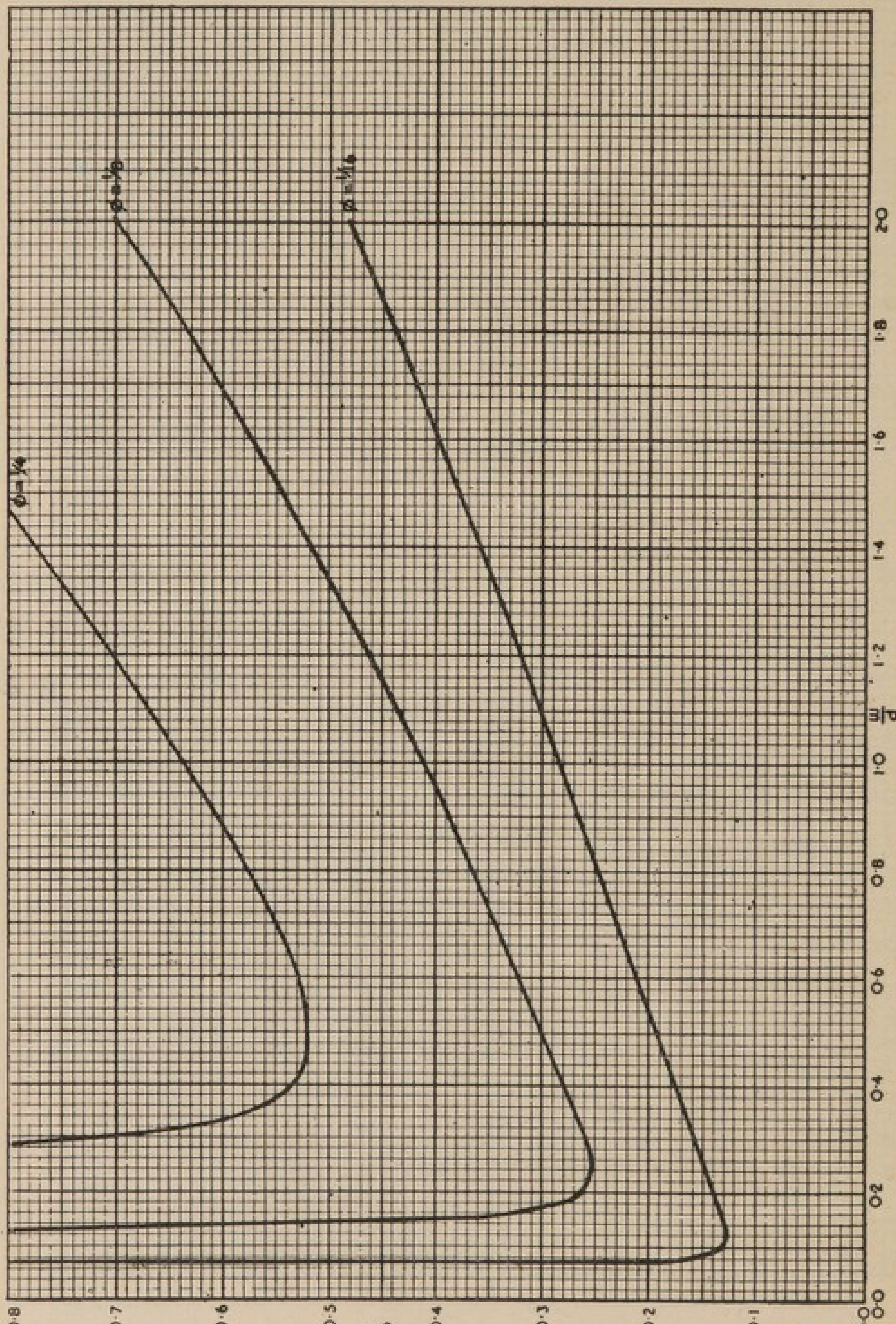


Fig. 63.

per cent we must have approximately 0·4 times d, and the area of the window must be about half as great again as is needed for the most efficient shape.

If we go to very long and low windows of the kind fitted in some recent houses it may be no longer correct to neglect the terms $\frac{1}{12}w^2$, but it is clear that such windows must have a large area compared with those of less extreme shapes. The curves of Figs. 62 and 63 have been calculated taking all terms into account.

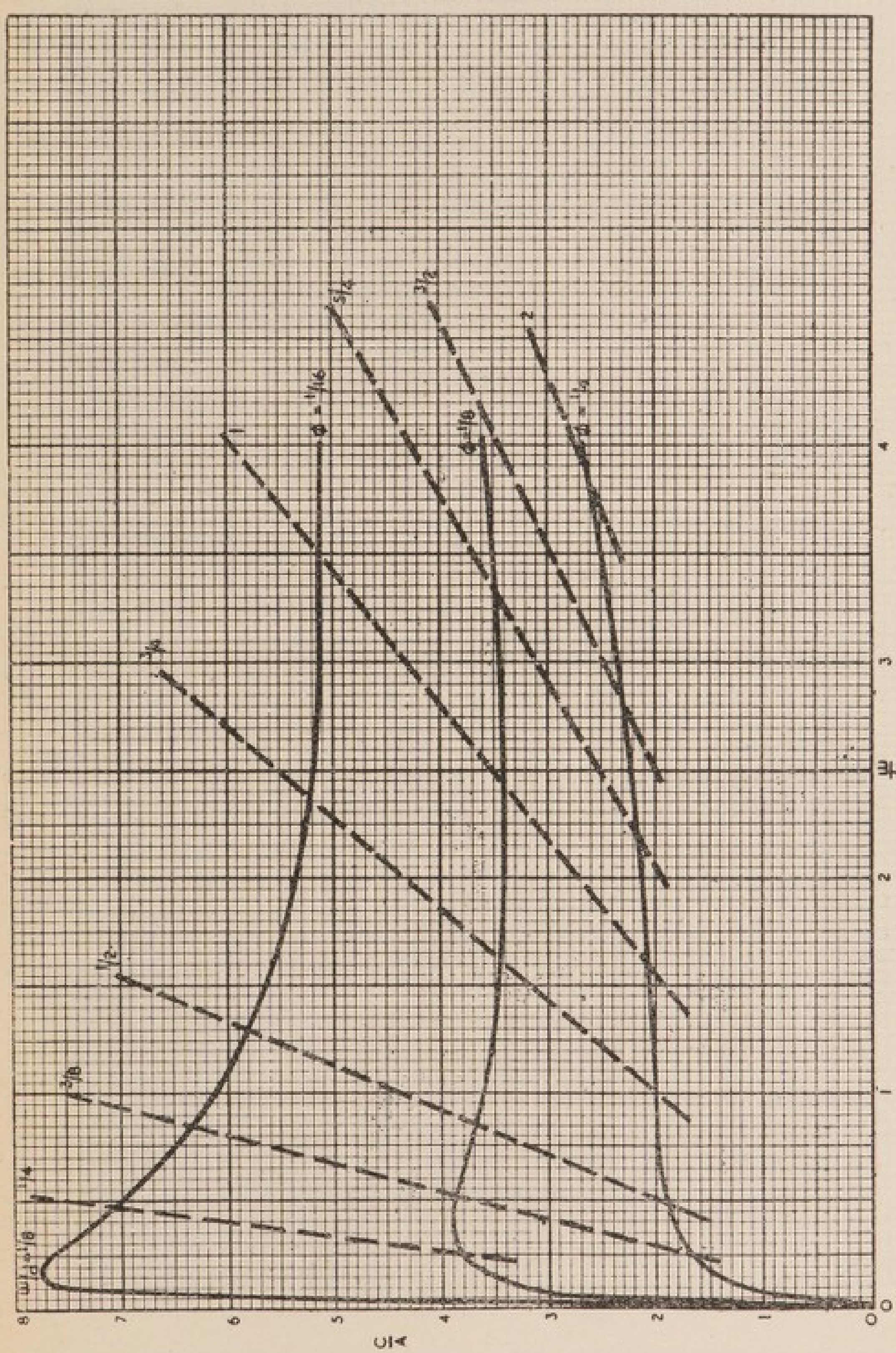


Fig. 64.

Those of Fig. 62 give the relation connecting the height and width of windows of equal penetration, and those of Fig. 63 the consequent changes in the area A.

In addition to the depth of penetration we require to know the area C enclosed by the contour where the illumination has the value ϕ. The contours are very approximately elliptical, with the minor axis equal to d. We can determine the

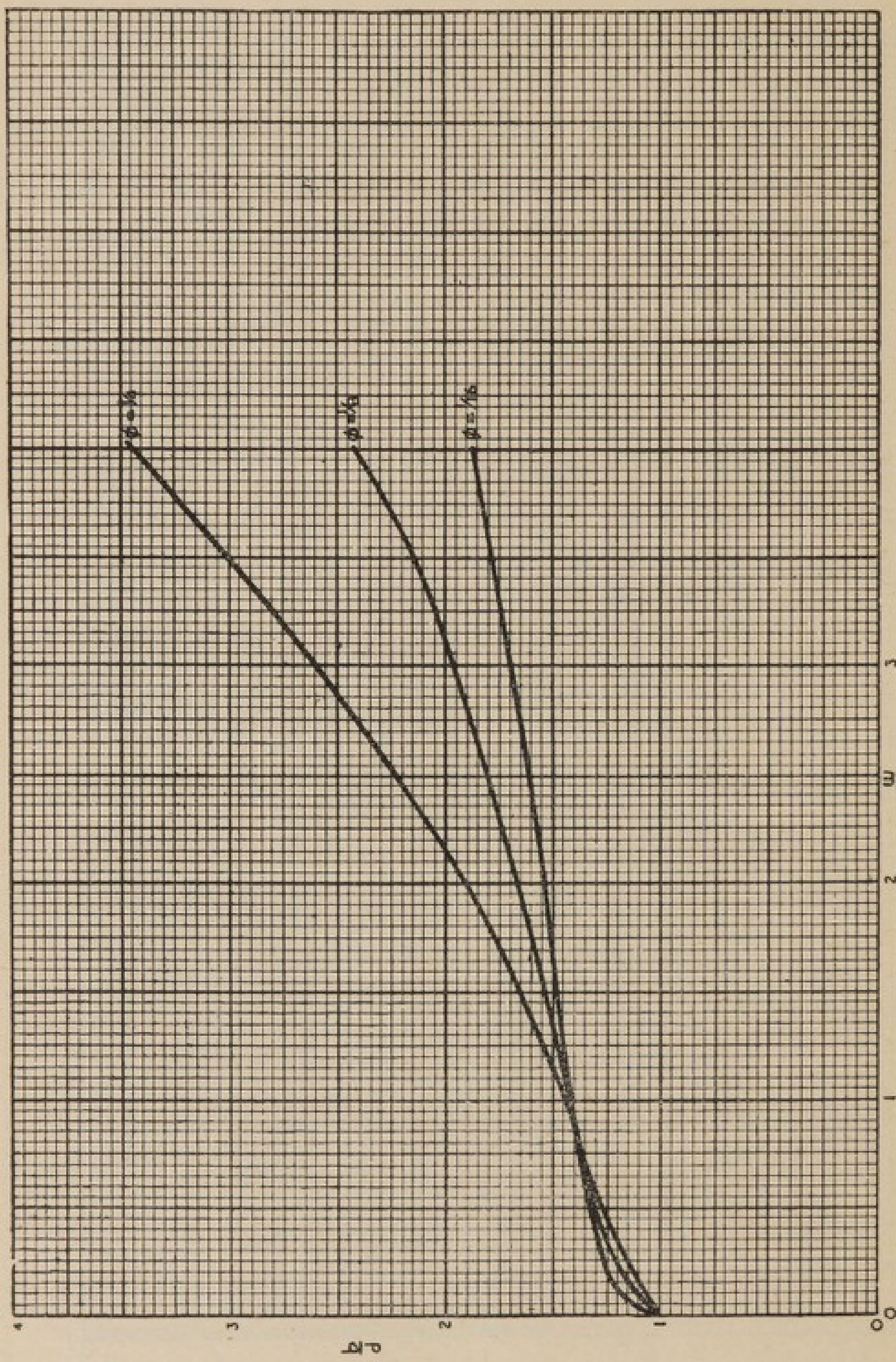


Fig. 65.

major axis b with sufficient accuracy by solving the original equation when x and y have been replaced by $\frac{1}{2}d$ and $\frac{1}{2}b$ respectively.

We note that when A is infinitely great the contour is a circle, so that the major axis is also equal to d. The ratio of window area to contour area is then infinitely great. When the window is narrow enough for w^2 to be neglected we obtain

$$b^4+2b^2(d^2+2h^2)-d^2(7d^2+4h^2)=0.$$

For the window of minimum area this gives	$b=d\times 1{\cdot}213$,
for the window of half this height	$b=d\times 1{\cdot}304$,
and for the window of one quarter this height	$b=\mathrm{d}\times 1{\cdot}339$.

The ratio A/C has a lower limit of approximately 2ϕ.

As the height is reduced the width of the window increases and the terms in w^2 cease to be negligible. The result is that b increases more rapidly, and the ratio of the window area to contour area increases less rapidly than the simplified equation suggests. Values derived from the full equation are shown in Fig. 64. For convenience the connection with depth of penetration has been included by inserting broken lines against which values of w/d have been recorded.

Finally, the connection between contour shape b/d and window shape w/h has been recorded in Fig. 65. For extremely high windows the contours are circular, and when the window width is about three-quarters of the height the contour shape has the inverse value $\frac{4}{3}$ for all the contours. As the window is made wider the 2 per cent contour shape leads to a value not very different from the window shape ratio, the 1 per cent contour shape changes at about half the rate of the 2 per cent, and the $\frac{1}{2}$ per cent at about half the rate of the 1 per cent ratio.

APPENDIX V

SURVEY OF DAYLIGHTING IN FLATS

In this survey the daylighting of sixty-two flats was examined in detail. Plans of each flat were studied at the Building Research Station and daylight contours drawn for all kitchens, living rooms, and bedrooms. The Wartime Social Survey section of the Ministry of Information provided investigators who then inspected each flat and questioned the occupiers. The investigators were trained observers and were given special instructions before commencing this survey. The survey was made in November 1942.

The information obtained is tabulated below, but before it is examined it should be noted, as a general point, that with very few exceptions the windows were of the size now required by the by-laws, *i.e.* they were equal to 10 per cent or more of the floor area. Some were much larger, being between 25 and 30 per cent of the floor area. This bore little relation to the daylighting, for in some such cases no direct natural light entered the rooms, and in others the maximum penetration did not exceed 2 or 3 ft. The occupants were very conscious of the deficiency, and found their consequent expenditure on artificial light a very considerable addition to the cost of living.

THE KITCHEN

Both tenants' and investigators' opinions of the kitchen were taken and analysed against various standards of daylight area and penetration.

Considering first the correlation between investigator's opinion and the daylight area for 2 per cent d.f., the following Table is obtained:

Table A. V/1. Opinion (Investigator)

Daylight area in sq. ft. of 2% d.f.	1		2		3		4		5		Total %	Total no. of cases
	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases		
0–5	0	0	3	1	22	7	25	8	50	16	100	32
6–10	0	0	17	3	67	12	11	2	5	1	100	18
11–15	0	0	25	1	25	1	50	2	0	0	100	4
16–20	0	0	100	4	0	0	0	0	0	0	100	4
21–25	0	0	100	1	0	0	0	0	0	0	100	one case only
Over 26	100	1	0	0	0	0	0	0	0	0	100	,,

Opinion: 1. Very good. 2. Good. 3. Fair. 4. Poor. 5. Very poor.

There are two things to establish here; first, that the Tables show a convincing trend of improvement in opinion with improvement in lighting; second, to confirm that the opinions to the investigators are themselves absolute and not adjusted in scale to each block of flats.

Table A. V/1 shows the opinions of all investigators against the daylight area for 2 per cent d.f. Each line is totalled to 100 per cent of the cases separately, so that the balance of opinion for each standard is shown clearly. It is interesting to observe that there is, in fact, a strongly marked trend of opinion; a majority feel that 0–5 sq. ft. daylight area is very poor. In the 6–10 and 11–15 classifications opinion is divided between poor and fair; at 16–20 sq. ft. opinion moves to good, and above this, though there are only two cases, they are both thought to be good.

The second objective is to show that the opinions of the investigators are reliable; *i.e.* that they are not adjusted within the worst and best of a single block of flats visited, but are based upon some absolute sense of what is good or bad. This point may be examined by separating out the opinions of investigators for different blocks, as in Tables A. V/2, 3 and 4. These show quite clearly that while Estate No. 1 had a wide gradient of lighting and a corresponding range of opinion, the two other estates for which results are given here had limited lighting and evoked a corresponding range of opinion.

Table A. V/2. Opinion (Investigator). Estate No. I (Modern)

Daylight area in sq. ft. of 2% d.f.	1		2		3		4		5		Cases
	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	
0–5	0	0	0	0	0	0	0	0	0	0	0
6–10	0	0	0	0	80	4	20	1	0	0	5
11–15	0	0	25	1	25	1	50	2	0	0	4
16–20	0	0	100	4	0	0	0	0	0	0	4
21–25	0	0	100	1	0	0	0	0	0	0	1
26–	100	1	0	0	0	0	0	0	0	0	1

Table A. V/3. Estate No. II (about 1930)

DAYLIGHT AREA IN SQ. FT. OF 2% D.F.	1		2		3		4		5		CASES
	%	CASES	%	CASES	%	CASES	%	CASES	%	CASES	
0–5	0	0	0	0	0	0	56	5	44	4	9
6–10	0	0	17	1	66	4	0	0	17	1	6
11–15	0	0	0	0	0	0	0	0	0	0	0
16–20	0	0	0	0	0	0	0	0	0	0	0
21–25	0	0	0	0	0	0	0	0	0	0	0

Table A. V/4. Estate No. III (about 1900)

DAYLIGHT AREA IN SQ. FT. OF 2% D.F.	1		2		3		4		5		CASES
	%	CASES	%	CASES	%	CASES	%	CASES	%	CASES	
0–5	0	0	20	1	80	4	0	0	0	0	5
6–10	0	0	34	2	66	4	0	0	0	0	6
11–15	0	0	0	0	0	0	0	0	0	0	0
16–20	0	0	0	0	0	0	0	0	0	0	0

The opinions of tenants and investigators also corresponded well, as is shown by comparing Tables A. V/1 and 5. Where the areas lighted to 2 per cent d.f. reached about 20 sq. ft., the investigators recorded an opinion of good (Table A. V/1), while at a roughly similar point the tenants record (Table A. V/5) that they are able to see "well."

Table A. V/5. Tenants' Opinion

DAYLIGHT AREA IN SQ. FT. OF 2% D.F.	1		2		3		CASES
	%	CASES	%	CASES	%	CASES	
0–5	0	0	27	9	73	24	33
6–10	0	0	55	10	45	8	18
11–15	0	0	25	1	75	3	4
16–20	80	4	20	1	0	0	5
21–25	100	1	0	0	0	0	1
26–	100	1	0	0	0	0	1

1. Tenant can see well. 2. All right. 3. Badly.

In order to compare opinion based on daylight area with opinion based on the penetration of the same standard of daylight, some further Tables, Nos. A. V/6 and 6A were prepared. These show the penetration of the 1 per cent d.f. Again the gradient of opinion is clear, moving into the "good" class with penetrations of, say, 3–4 ft.

Table A. V/6. Investigators' Opinion

Penetration of 2% D.F. in ft.	1		2		3		4		5		Cases
	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	
0–1	0	0	0	0	18	5	22	6	60	16	27
1–2	0	0	16	1	16	1	50	3	16	1	6
2–3	0	0	18	3	75	12	7	1	0	0	16
3–4	0	0	50	3	17	1	33	2	0	0	6
4–5	0	0	75	3	25	1	0	0	0	0	4
5–	100	1	0	0	0	0	0	0	0	0	1

Table A. V/6a. Tenants' Opinion in Winter Penetration 2% d.f.

Penetration of 2% D.F. in ft.	1		2		3		Cases
	%	Cases	%	Cases	%	Cases	
0–1	0	0	19	5	81	21	26
1–2	0	0	33	2	67	4	6
2–3	0	0	62	10	28	6	16
3–4	33	2	17	1	50	3	6
4–5	75	3	25	1	0	0	4
5–	100	1	0	0	0	0	1

Other Tables for the 0·5 per cent d.f. show a similar correspondence.

Tables A. V/7 and 7a illustrate the same point for the 1 per cent d.f., the "good" class being reached at a penetration of about 5 ft.

Table A. V/7. Investigators' Opinion

Penetration of 2% D.F. in ft.	1		2		3		4		5		Cases
	%	Cases	%	Cases	%	Cases	%	Cases	%	Cases	
0–2	0	0	0	0	15	3	30	6	55	14	23
2–4	0	0	16	3	60	12	12	2	12	2	19
4–6	0	0	40	6	40	6	20	3	0	0	15
6–	33	1	67	2	0	0	0	0	0	0	3

Table A. V/7a. Tenants' Opinion

Penetration of 1% D.F. in ft.	1		2		3		Cases
	%	Cases	%	Cases	%	Cases	
0–2	0	0	13	3	87	20	23
2–4	0	0	55	10	45	8	18
4–6	20	3	40	6	40	6	15
6–	100	3	0	0	0	0	3

An examination of all individual cases which were judged to be well lighted by both the tenants and the investigators showed that in all instances the penetration of the 2 per cent d.f. exceeded 5 to 6 ft., and the area lighted to this value exceeded 16 sq. ft.

Analyses of decoration were made which indicated that people who have light decorations are not necessarily satisfied, but the people who are satisfied do have light decoration.

The three principal tasks or locations of work in kitchens, the sink, the cooker, and work-table, were examined separately, in terms both of direct opinion of daylighting, and evidence by the use of artificial light.

Table A. V/8 shows an unexpected reversal of opinion at higher values of illumination, though up to 2 per cent the trend is fairly clear.

TABLE A. V/8. SINKS. TENANTS' OPINION IN WINTER

D.F.	1		2		3		TOTAL CASES
	%	CASES	%	CASES	%	CASES	
0–0·5	0	0	24	6	76	19	25
0·5–1·0	10	1	60	6	30	3	10
1·0–2·0	40	2	40	2	20	1	5
2·0–5·0	0	0	67	6	33	3	9
5·0–	15	2	46	6	39	5	13

Table A. V/9 shows the opinion in summer on the same question.

TABLE A. V/9. SINKS. TENANTS' OPINION IN SUMMER

D.F.	1		2		3		TOTAL CASES
	%	CASES	%	CASES	%	CASES	
0–0·5	6	2	44	11	50	12	25
0·5–1·0	20	2	60	6	20	2	10
1·0–2·0	80	4	20	1	0	0	5
2·0–5·0	44	4	44	4	12	1	9
5·0–	54	7	46	6	0	0	13

The Table for summer opinion has a clear trend, the bad cases remaining bad and the good cases being improved as compared with winter opinions.

From both Tables it may be judged that values below 1·0 per cent d.f. are unsatisfactory. Between 1 and 2 per cent there is no clear choice, though there is a trend toward satisfaction at 2·0 per cent.

It is worth while considering whether, in the cases of declared dissatisfaction at higher values of daylight, it is necessary to use the electric light in winter as an aid. This is shown in Table A. V/10.

TABLE A. V/10. WINTER USE OF ARTIFICIAL LIGHT AS AN AID TO DAYLIGHT

D.F.	NEVER		OCCASIONALLY		OFTEN		TOTAL CASES
	%	CASES	%	CASES	%	CASES	
0–0·5	12	3	25	5	63	17	25
0·5–1·0	30	3	50	5	20	2	10
1·0–2·0	80	4	0	0	20	1	5
2·0–5·0	33	3	33	3	33	3	9
5·0–	15	2	54	7	30	4	13

The curious thing is that this Table does have a reversal of opinion of higher values which roughly corresponds to Table A. V/8, which would seem to show at least that people do confirm their opinion of the daylighting by their practice in supplementing it by artificial light.

It was found by studying individual cases, that where people see badly at the sink in winter with 5 per cent d.f., they all complain of the room as a whole, in winter.

There is no evidence that people in one block of flats differ from another in their general reaction to daylight. In the best lighted estate and in a second-rate group, opinions at the sink for a 5 per cent d.f. show the same dispersal of opinion.

For the cooker, the following Tables are relevant:

TABLE A. V/11. TENANTS' OPINION, IN WINTER

D.F.	1		2		3		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0–0·5	0	0	31	14	69	31	45
·5–1·0	67	4	0	0	33	2	6
1·0–2·0	10	1	20	2	70	7	10
2·0–5·0	0	0	0	0	0	0	0
5·0–	0	0	0	0	0	0	0

TABLE A. V/12. USE OF ARTIFICIAL LIGHT

D.F.	NEVER		OCCASIONALLY		OFTEN		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0–0·5	13	6	20	9	66	30	45
0·5–1·0	67	4	0	0	33	2	6
1·0–2·0	10	1	30	3	60	6	10
2·0–5·0	0	0	0	0	0	0	0
5·0–	0	0	0	0	0	0	0

N.B.—No cooker, except on one estate, had better than 1 per cent and, except in two cases, none were above 0·5 per cent.

The correlation in these Tables is good, and the results seem reasonable. Nobody has a higher d.f. than 2 per cent at the cooker, and a large majority feel it inadequate.

For the work-table, the following are the relevant Tables:

TABLE A. V/13. TENANTS' OPINION, IN WINTER

D.F.	1		2		3		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0–0·5	0	0	27	10	73	27	37
0·5–1·0	0	0	64	9	36	5	14
1·0–2·0	0	0	67	2	33	1	3
2·0–5·0	0	0	100	1	0	0	1
5·0–	67	4	16	1	16	1	6

TABLE A. V/14. USE OF ARTIFICIAL LIGHT AS SUPPLEMENT

D.F.	NEVER		OCCASIONALLY		OFTEN		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0–0·5	10	4	20	8	70	25	37
0·5–1·0	43	6	36	5	21	3	14
1·0–2·0	66	2	0	0	33	1	3
2·0–5·0	100	1	0	0	0	0	1
5·0–	83	5	0	0	17	1	6

On these Tables the trend is consistent. Dissatisfaction is evident at 0·5 per cent, but by 2 per cent it has swung round to satisfaction, at least, in that artificial light does not seem to be required.

THE LIVING ROOM

This is, in general, the largest and the deepest room in flats, and it follows that the daylight requirements in respect of area and penetration may be more exacting than elsewhere. The living room ranges in size from 125 sq. ft. to 175 sq. ft. and the average of all the living rooms is 153·6 sq. ft.

By a mischance, the tenants' opinion of the daylight as a whole was not taken, but that of the investigator was. The investigators' and tenants' opinions correlated well on kitchens and may be assumed to do so here. Tenants' opinions on the lighting near the fireplace and on the table were taken.

From Table A. V/15 the trend is clear, and there seems a substantial opinion that somewhere between a daylight area of 66 and 115 sq. ft. conditions were thought reasonable.

TABLE A. V/15. INVESTIGATORS' OPINION (WINTER)
ROOM AS A WHOLE

DAYLIGHT AREA IN SQ. FT. OF 1% D.F.	1		2		3		4		5		NO. OF CASES
	%	CASES	%	CASES	%	CASES	%	CASES	%	CASES	
0–15	0	0	13	1	37	3	25	2	25	2	8
16–40	0	0	57	8	36	5	6	1	0	0	14
41–65	11	2	28	5	44	8	17	3	0	0	18
66–90	13	1	62	11	25	4	0	0	0	0	16
91–115	0	0	67	4	16	1	16	1	0	0	6
116–130	100	1	0	0	0	0	0	0	0	0	1

From Table A. V/16 a penetration of the 1 per cent d.f. of, say, 8–10 ft. seems to remove the rooms from "fair" to "good."

TABLE A. V/16. INVESTIGATORS' OPINION (WINTER)
ROOM AS A WHOLE

PENETRATION OF 1% D.F.	1		2		3		4		5		NO. OF CASES
	%	CASES	%	CASES	%	CASES	%	CASES	%	CASES	
0–2	0	0	14	1	14	1	43	3	28	2	7
2–4	0	0	67	4	16	1	16	1	0	0	6
4–6	0	0	28	4	43	6	28	4	0	0	14
6–8	13	3	45	10	42	9	0	0	0	0	22
8–10	0	0	86	7	12	1	0	0	0	0	8
10–over	33	1	67	2	0	0	0	0	0	0	3

Opinion: 1. Very good. 2. Good. 3. Fair. 4. Poor. 5. Very poor.

Tenants' opinions were taken for a point near the fireplace with the suggestion of reading or sewing.

Table A. V/17 shows the daylight values and tenants' opinion.

TABLE A. V/17. NEAR THE FIREPLACE—TENANTS' OPINION (WINTER)

D.F.	1		2		3		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0	6	2	30	10	64	21	33
0·5	28	3	36	4	36	4	11
1·0	34	4	50	6	16	2	12
2·0	0	0	100	1	0	0	1
3·0	33	1	67	2	0	0	3
5·0	0	0	0	0	0	0	0

1. Tenant can see well. 2. Tenant can see all right. 3. Tenant can see badly.

The movement of opinion is fairly clear up to a standard of 1·0 per cent d.f., above which the number of cases is probably too few to be very significant. At

1·0 per cent d.f. some people could see "well," and a majority "all right," but below this, a substantial number felt they could see only "badly."

Tenants' opinions were also taken at the dining table, for eating in the living room. Table A. V/18 shows the results for winter. Again the number of cases above 1·0 per cent d.f. is hardly significant, but a majority felt the light was "all right" at this value, and none found it "bad" at higher values.

TABLE A. V/18. AT THE TABLE—TENANTS' OPINION (WINTER)

D.F.	1		2		3		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0	0	0	40	6	60	9	15
0·5	17	1	33	2	50	3	6
1·0	19	4	71	15	10	2	221
2·0	0	0	100	3	0	0	3
3·0	33	2	67	3	0	0	6
5·0	67	4	33	2	0	0	6

1. Tenant can see well. 2. Tenant can see all right. 3. Tenant can see badly.

The evidence by the use of artificial light in this room supports the data obtained thus far. Table A. V/19 is the counterpart to Table A. V/15 and shows that people stop using artificial light as a supplement round about a daylight area of 90–115 sq. ft.

TABLE A. V/19. USE OF ARTIFICIAL LIGHT (ROOM AS A WHOLE)

DAYLIGHT AREA OF 1% D.F.	NEVER		OCCASIONALLY		OFTEN		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0–15	0	0	25	2	75	6	8
16–40	7	1	57	8	36	5	14
41–65	0	0	83	15	17	3	18
66–90	37	6	54	9	9	1	16
91–115	66	4	33	2	0	0	6
116–130	100	1	0	0	0	0	1

TABLE A. V/20. USE OF ARTIFICIAL LIGHT (ROOM AS A WHOLE)

PENETRATION 1% D.F.	NEVER		OCCASIONALLY		OFTEN		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0–2	0	0	42	3	58	4	7
2–4	17	1	50	3	33	2	6
4–6	0	0	70	10	30	4	14
6–8	14	3	68	15	18	4	22
8–10	50	4	50	4	0	0	8
10 and over	100	3	0	0	0	0	1

Table A. V/20 is the counterpart of Table A. V/16 and is also confirmatory, showing the use of artificial light to stop at about 8–10 ft. penetration.

BEDROOM

The flats selected were one-, two-, and three-bedroom types. Consequently the bedrooms are of somewhat varying sizes, although the range is only from 87 to 135 sq. ft., and only a very small number of these were under 100 sq. ft., the average being 117·4 sq. ft. They are here analysed together regardless of their relative size of importance. The use of artificial light during daytime in these cases does not necessarily correspond with daylighting conditions, as in many cases bulbs have been taken out of their fittings, and there is a reluctance to use artificial light even when the daylight is bad.

Both the tenants' and investigators' opinions in winter of each bedroom as a whole were taken and analysed against various standards of the daylight area for 0·5 per cent d.f.

TABLE A. V/21. INVESTIGATORS' OPINION

DAYLIGHT AREA OF 0·5% D.F.	1		2		3		4		5		NO. OF CASES
	%	CASES	%	CASES	%	CASES	%	CASES	%	CASES	
0–15	0	0	0	0	23	3	31	4	46	6	13
16–40	8	2	28	7	44	11	12	3	8	2	25
41–65	8	2	41	12	31	9	10	3	10	3	29
66–90	0	0	24	4	59	10	17	3	0	0	17
91–115	25	1	50	2	25	1	0	0	0	0	4

Opinion : 1. Very good. 2. Good. 3. Fair. 4. Poor. 5. Very poor.

TABLE A. V/22. TENANTS' OPINION

DAYLIGHT AREA OF 0·5% D.F.	1		2		3		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0–15	0	0	33	6	67	12	18
16–40	17	5	48	14	35	10	29
41–65	31	11	47	17	22	8	36
66–90	21	3	64	9	15	2	14
91–115	60	3	40	2	0	0	5

1. Tenant can see well. 2. Tenant can see all right. 3. Tenant can see badly.

Table A. V/21 and Table A. V/22 show tenants' and investigators' opinions and exhibit definite correlation. It would appear that a daylight area of 66–90 sq. ft. gives fair daylighting and anything over 90 sq. ft. will give satisfaction.

A consideration of investigators' and tenants' opinions, as related to penetration of 0·5 per cent d.f., shows that a penetration of 6–8 ft. gives fair daylight conditions and 8–10 would prove satisfactory. This latter figure is in agreement with a daylight area of about 90 sq. ft.

TABLE A. V/23. INVESTIGATORS' OPINION (WINTER)

PENETRATION 0·5% D.F.	1		2		3		4		5		NO. OF CASES
	%	CASES	%	CASES	%	CASES	%	CASES	%	CASES	
0	0	0	0	0	28	4	36	5	36	5	14
2	0	0	12½	1	75	6	0	0	12½	1	8
4	7	1	33	5	8	53	8	0	7	1	15
6	10	2	24	5	33	7	19	4	14	3	21
8	11	3	37	10	41	11	11	3	0	0	27
10 and over	20	1	40	2	0	0	20	1	20	1	5

Opinion: 1. Very good. 2. Good. 3. Fair. 4. Poor. 5. Very poor.

TABLE A. V/24. TENANTS' OPINION (WINTER)

PENETRATION 0·5% D.F.	1		2		3		NO. OF CASES
	%	CASES	%	CASES	%	CASES	
0	0	0	31	5	69	11	16
2	0	0	75	6	25	2	8
4	29	5	53	9	18	3	17
6	24	5	43	9	33	7	21
8	38	9	54	13	8	2	24
10 and over	29	2	42	3	29	2	7

1. Tenant can see well. 2. Tenant can see all right. 3. Tenant can see badly.

The results shown in both Tables for a penetration of 10 ft. and over called for closer examination when it was seen that, although the penetration is good, the daylight area is comparatively small and badly distributed in relation to the shape of the room, which in both cases is in a re-entrant angle of the block with a window in a 45° splay wall.

GENERAL NOTES

Income Groups—three groups were contemplated with the wages of the principal earner as follows: up to £187 p.a., £187–£260 p.a. and over £260 p.a.
The cases were divided as follows:

Up to £187	37 per cent
£187–£260	63 ,, ,,
Over £260	0 ,, ,,

Tenants were asked how long they had been in their flats, with the following result:

Under 3 years	31 per cent
3–6 ,,	36 ,, ,,
7–10 ,,	20 ,, ,,
11–14 ,,	10 ,, ,,
15 & over	3 ,, ,,

APPENDIX VI. LIGHTING OF DWELLINGS

By Dennis Chapman assisted by Geoffrey Thomas

An Inquiry by the Wartime Social Survey

CONTENTS

0. INTRODUCTION

0. 1. The Department of Scientific and Industrial Research are convenors of the Committee on the Lighting of Buildings. This Committee is studying the lighting requirements of post-war buildings. In order that provision can be made for efficient, natural, and artificial lighting it was considered necessary to examine a sample of existing houses and to measure and describe their lighting. It was also considered desirable to find out what the housewife, who is the principal member of the family concerned, thought about artificial and natural lighting in relation to the main activities within the house. These objective facts and subjective impressions are related in the Report to geographical region, to type and age of dwelling, to income group, and to cost of electricity. (The Survey was confined to houses with electric lighting.)

0. 2. The inquiry was concerned with the following:

a. A detailed analysis of the artificial lighting of the main downstair rooms. This included the size of the lamps, their position and the type of fitting, the dimensions of the rooms, and the colour of the walls and ceilings. The amount of light in the main working positions was measured with a light meter. The influence of cost of electricity on the amount used was studied.

b. How well the housewife thought she could see when doing her housework by artificial light and how well she thought the children could see when doing their homework by artificial light.

c. Whether or not there was direct daylight at the main working positions in the scullery, kitchen, living room, and parlour.

d. How well the housewife thought she could see when doing her housework by daylight, and how well she thought the children could see when doing their homework by daylight.

e. To what extent it is necessary to supplement daylighting by artificial lighting.

f. Where the main rooms receive sunlight at present and housewives' preferences for aspect.

The nature of the main part of the inquiry—which required a considerable amount of measurement, the putting up of the blackout and careful observation—would have left a gap in the interview during which the housewife would have been a mere spectator. We therefore added certain extra questions related to fuel economy for the Ministry of Fuel and Power. These questions appear in the questionnaire, but the analysis has been made separately.

1. SAMPLE

1. 1. The inquiry was planned on a basis of three thousand interviews, distributed regionally in proportion to the population. In the time at our disposal it was not possible to obtain more than 2375 interviews, however, and there is some inequality in the regional distribution as a result.

The sample was designed to give equal numbers in three income groups, but in practice this aim was not quite realized. The difference was, however, unimportant.

The procedure adopted to choose households for interview was this :

1. Each investigator was given a list containing three or four series of random numbers, taken from a list of random numbers up to one hundred, arranged in three income groups. Each series represented a street, and the numbers the house numbers in the street.
2. The investigator, in consultation with the electricity company, chose a number of streets equal to the number of series of random numbers on her list, each street being in one of the income groups and containing houses lit by electricity. Houses with numbers corresponding to those on the list were then visited.

The sample is subject to three general limitations imposed by the nature of the survey:

1. It was taken in Urban areas only.
2. Roughly equal numbers were chosen in each income group.
3. Only homes lit by electricity were visited.

A numerical analysis of the sample is as follows :

1. BY INCOME GROUP (Wage of principal wage-earner)

i. Up to £3. 12*s*	724	30·5%
ii. £3. 12*s*–£5	890	37·6%
iii. £5–£10	752	31·7%
Unclassified	9	
	2375	

In a normal sample, group i. would be approximately 35 per cent, group ii. 40 per cent, and group iii. 20 per cent, leaving 5 per cent of the population unrepresented. We do not, however, know the proportions in which that part of the population using electricity is distributed :

2. BY REGION

1. Scotland	309
2. N., N.E., and N.W.	571
3. Midlands and E.	568
4. London and S.E.	387
5. S., S.W., and Wales	540
	2375

Here the N., N.E., and N.W. and London and S.E. are somewhat under-represented.

3. BY AGE OF DWELLING

1. Pre-War Dwellings (pre 1914)	1305
2. Post-War Dwellings (post 1919)	1058
Unclassified	12
	2375

Choosing houses lit only by electricity does not appear to have biased the sample in respect to age of dwelling as there are about $7\frac{1}{2}$ million pre-war dwellings and about $5\frac{1}{2}$ million post-war dwellings.

4. BY HOUSE OR FLAT

1. Houses	1969
2. Flats	396
Unclassified	10
	2375

5. BY COST OF ELECTRICITY PER UNIT

1. Up to 3*d*.	1415
2. 3*d*. to $4\frac{1}{2}$*d*.	435
3. Over $4\frac{1}{2}$*d*.	478
Unclassified	47
	2375

NOTE

Any total figures given in tables should not be taken as representing the national position. This could only be calculated if the correct proportions of the income groups with electricity and the correct proportions in regions, in old and new houses, in houses and flats and paying different prices for electricity were known.

The following towns were visited in the course of the investigation :

Glasgow	Sheffield	Kidderminster
Edinburgh	Leicester	Wolverhampton
Dundee	Nottingham	Guildford
Aberdeen	Derby	Portsmouth
Carlisle	Preston	Salisbury
Manchester	Luton	Cardiff
Bolton	Northampton	Bristol
Lancaster	Lincoln	Exeter
Stoke	Ipswich	Plymouth
Newcastle	Norwich	Ebbw Vale
Middlesbrough	Maidstone	Llanelly
Leeds	Reading	Swansea
York	Oxford	London
Huddersfield	Birmingham	Rochester
	Tewkesbury	Chatham

The number of interviews carried out in these towns was from 20 to 160.

TABLE I

Refers to paragraphs 2. 2 and 2. 3

TOTAL WATTS FOR ALL ROOMS

Analysis by Income

SCULLERY OR WORKING KITCHEN

	UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM		ALL INCOMES	
	No.	%	No.	%	No.	%	No.	%
Up to 25	247	46	246	33	171	25	664	34
26–50	170	32	317	43	254	37	741	38
51–75	114	21	158	21	227	33	499	26
76 and over	6	1	18	2	30	4	54	2
ALL WATTAGES	537	100	739	100	682	100	1958	100
No such room	88		89		25		202	
No answer and does not apply	99		62		45		206	
SAMPLE	724		890		752		2366	

KITCHEN LIVING ROOM

	UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM		ALL INCOMES	
	No.	%	No.	%	No.	%	No.	%
Up to 25	24	4	16	2	13	3	53	3
26–50	136	20	94	13	62	12	292	16
51–75	353	55	405	56	221	44	979	52
76 and over	131	21	207	29	205	41	543	29
ALL WATTAGES	644	100	722	100	501	100	1867	100
No such room	66		163		242		471	
No answer and does not apply	14		5		9		28	
SAMPLE	724		890		752		2366	

SITTING ROOM OR PARLOUR

	UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM		ALL INCOMES	
	No.	%	No.	%	No.	%	No.	%
Up to 25	32	10	23	4	12	2	67	4
26–50	73	23	64	12	54	8	191	13
51–75	178	55	292	54	201	32	671	45
76 and over	39	13	159	30	364	58	562	48
ALL WATTAGES	322	100	538	100	631	100	1491	100
No such room	319		241		44		604	
No answer and does not apply	83		111		77		271	
SAMPLE	724		890		752		2366	

Income Unclassified 9

SECTION I

2. LIGHTING ANALYSIS OF THE MAIN DOWNSTAIR ROOMS

2. 1. A detailed examination of the artificial lighting of the scullery or working kitchen, the kitchen living room, and the sitting room and parlour was made. This comprised the following observations :

i. The size of the lamps and their total wattage.
ii. The dimensions of the room.
iii. The position of the electric lighting fittings.
iv. The type of fittings.
v. The colour of the walls.
vi. The colour of the ceiling.
vii. A series of light-meter readings taken at the sink, the cooker, the table in the kitchen both unshadowed and as used, and in the living room or parlour 5 ft. from the fire and 3 ft. from the ground. This latter point was chosen as being about the place where the housewife would be when reading or sewing.

All these observations have been related to the questions asked about the adequacy of artificial lighting.

TOTAL WATTS AVAILABLE

2. 2. In this analysis all rooms were described separately. In the case of the scullery and working kitchen 34 per cent of them were lighted with lamps which had a wattage of 25 or less, 38 per cent had 26 to 50 watts, 26 per cent 51 to 75 watts, and 2 per cent 76 to 100 watts.

The kitchen living room had larger lamps : only 3 per cent had up to 25 watts, 16 per cent had 26 to 50 watts, 52 per cent 51 to 75 watts, 24 per cent 76 to 100 watts, and 5 per cent had over 100 watts.

(The distribution of lamps in the kitchen living room is given in Statistical Table 1 for reference.)

The sitting room or parlour had even larger lamps, only 4 per cent had up to 25 watts, 13 per cent 26 to 50 watts, 45 per cent 51 to 75 watts, 23 per cent 76 to 100 watts, and 15 per cent had over 100 watts. (Refers to Table 1.)

It should be noted that in one-third of dwellings the size of lamps has been reduced since the war. (Paragraph 7. 9.)

COMPARISON OF INCOME GROUPS

2. 3. In every case this analysis shows that in the high income groups the rooms have lamps with greater wattage. In the scullery or working kitchen 46 per cent of the lowest income group have up to 25 watts, whereas in the highest income group the proportion is 25 per cent. In the kitchen living room, in the lowest income group 21 per cent have over 75 watts, whereas in the highest income group the proportion is 41 per cent. Likewise in the sitting room or parlour, in the lowest income group, the proportion with over 75 watts is 13 per cent compared with 58 per cent. (Table 1.)

The average watts in each income group in the kitchen living room was as follows :

Under £187 per annum	65 watts
£187–£260 ,,	71 ,,
£260–£520 ,,	82 ,,

ANALYSIS BY COST OF ELECTRICITY

2. 4. Electricity costs were grouped into three price ranges: up to and including 3*d.* per unit (of which about half were rates up to ½*d.* per unit, plus a standing charge, one-third from ½*d.* to 1*d.* per unit, plus a standing charge, one-fifth from over 1*d.* to 3*d.* per unit without a standing charge, and the rest were combinations of other rates all being less than 3*d.*),[1] over 3*d.* and including 4½*d.* per unit and over 4½*d.* per unit.

An analysis of the size of lamps by cost of electricity showed that as the cost of electricity went up the size of lamps went down. This is best demonstrated by the average wattage as shown below for the kitchen living room:

COST OF ELECTRICITY	AVERAGE SIZE OF LAMP
Up to and including 3*d.* per unit	78 watts
Over 3*d.* and up to and including 4½*d.*	67 "
Over 4½*d.* per unit	58 "

Separate analyses were made for each room and by income groups. These showed that not only did the size of lamp go down as the cost of electricity went up, but that this was true in each income group, and that at each cost the size of lamps varied with the annual income of the principal wage earner.

WATTS ANALYSED IN RELATION TO THE HOUSEWIFE'S STATEMENT ABOUT HER ABILITY TO SEE WHEN DOING CERTAIN JOBS

2. 5. The answers of the housewife to the question "How are you able to see when doing the following jobs by artificial light," were analysed according to the total watts in the rooms concerned, and the results show a certain relationship between the amount of light available and the housewife's opinion, although this relationship is less clear in the kitchen than in the sitting room.

The reason for this is probably that in the living room the housewife can adjust her position for reading or sewing in relation to light, but in the kitchen her position is often determined by the location of the sink, cooker, or kitchen table. As the light is usually placed in the centre of the room, the housewife is often in her own light.

Washing-up. Of those housewives who had less than 25 watts, 28 per cent said they could see well, 47 per cent all right, and 25 per cent badly; of those who had 50 watts the proportions were 39 per cent, 47 per cent, and 14 per cent; and of those who had 75 watts or more the proportions were almost exactly the same, 38 per cent, 48 per cent, and 14 per cent.

Preparing Food. Of the housewives who had less than 25 watts in their kitchens, 32 per cent said they could see well, 50 per cent all right, and 18 per cent badly; in the case of those who had 50 per cent watts the proportions were 40 per cent, 51 per cent, and 9 per cent.

Cooking. The answers to the question about cooking followed very closely those of the two previous questions. Of those who had 25 watts, 30 per cent said they could see well, 46 per cent all right, 24 per cent badly; of those who had 50 watts, 40 per cent said they could see well, 47 per cent all right, and 13 per cent badly; and of those who had 75 watts or more the proportions were exactly the same.

Reading and Sewing in the Kitchen Living Room. The possibility of adjusting one's position to the lighting for reading or sewing is made evident in the clearer divisions in this analysis. As has already been seen the kitchen living room and the sitting room are somewhat better lighted than the scullery or working kitchen, only a small proportion having as little as 25 watts.

This analysis shows a very much higher proportion able to see well in rooms which are better lighted, as is shown below:

TOTAL WATTS	WELL %	STD. DEV.	ALL RIGHT %	STD. DEV.	BADLY %	STD. DEV.	ALL = 100% No.
Up to 50	35	± 2·6	50	± 2·7	15	± 2·0	334
51–75	48	± 1·6	46	± 1·6	6	± ·8	959
76 and over	53	± 2·2	44	± 2·1	3	± ·7	535

Note: About 2 per cent of those with a kitchen living room did not answer the question, and for total watts rather less than 2 per cent were unknown.

[1] There were sufficient cases in the first two groups to permit of a separate analysis of the watts in the kitchen living room, and this analysis showed a significant difference between the two groups and provided further evidence of the effect of the cost of electricity on the number of watts used.

Reading and Sewing in Sitting Room or Parlour. The analysis of this question follows closely that of the previous question and shows that housewives' opinions of their lighting is much higher where the rooms are, in fact, better lighted.

TOTAL WATTS	WELL %	STD. DEV.	ALL RIGHT %	STD. DEV.	BADLY %	STD. DEV.	ALL=100% No. 1
Up to 50	42	± 3·0	49	± 3·0	9	± 1·8	240
51–75	55	± 2·0	41	± 2·0	4	± ·8	635
76 and over	58	± 2·1	38	± 2·1	3	± ·7	546

Note: Rather more than 4 per cent of those with a sitting room or parlour did not answer the question, and for total watts 4 per cent were unknown.

The position is summarized in the statement below which gives the average watts available to housewives who see "Well," "All right" and "Badly" for the different jobs.

JOB	AVERAGE WATTS AVAILABLE		
	Well	All Right	Badly
Cooking in Kitchen or Scullery	40	37	31
Washing-up in Kitchen or Scullery	40	37	31
Preparing Food in Kitchen or Scullery	39	37	31
Reading and Sewing in Kitchen Living Room	70	66	56
Reading and Sewing in Sitting Room or Parlour	79	73	61

WATTS PER SQUARE FOOT

2. 6. The size of lamps used in each room has been analysed in relation to the area to be lighted and the number of watts per square foot computed.

44 per cent of sculleries were found to have up to half a watt per square foot, 39 per cent up to one watt per square foot, 11 per cent up to one and a half watts per square foot, and 6 per cent had more than one and a half watts per square foot.

In the kitchen living room the proportions were 54 per cent up to half a watt per square foot, 40 per cent up to one watt per square foot, 4 per cent up to one and a half watts per square foot, and 2 per cent had more than one and a half watts per square foot. Thus the kitchen living room was less well lighted than the scullery.

In the sitting room the proportions were 56 per cent, 38 per cent, 4 per cent, and 1 per cent.

Thus, although the number of watts available was greater in the kitchen living room than in the scullery, and greater still in the sitting room, the differences were not proportional to the increases in room area; the scullery was therefore best lighted and the sitting room worst lighted in watts per square foot. (Refers to Table 2.)

TABLE 2

WATTS PER SQUARE FOOT FOR ALL ROOMS

Refers to paragraph 2. 6

WATTS PER SQUARE FOOT	SCULLERY OR WORKING KITCHEN		KITCHEN LIVING ROOM		SITTING ROOM	
	No.	%	No.	%	No.	%
Up to ·50	852	44	998	54	841	56
·51–1·00	770	39	744	40	573	38
1·01–1·50	216	11	79	4	62	4
1·51 and over	116	6	38	2	15	1
ALL MEASUREMENTS	1954	100	1859	100	1491	100
No such room, no light and no answer	421		516		884	
SAMPLE	2375		2375		2375	

COMPARISON OF HOUSES AND FLATS

2. 7. In each case the lighting of flats was significantly better than that of houses as the following abstract shows :

	SCULLERY AND WORKING KITCHEN				KITCHEN LIVING ROOM				SITTING ROOM OR PARLOUR			
	House %	Std. Dev.	Flat %	Std. Dev.	House %	Std. Dev.	Flat %	Std. Dev.	House %	Std. Dev.	Flat %	Std. Dev.
Up to ½ watt per square foot	46	± 1·1	26	± 2·6	55	± 1·2	48	± 2·9	58	± 1·4	49	± 3·4
Over ½ watt per square foot	54	± 1·1	74	± 2·6	45	± 1·2	52	± 2·9	42	± 1·4	51	± 3·4

KITCHEN LIVING ROOM

COST	UP TO AND INCLUDING ½*d.* PER UNIT +STANDING CHARGE		OVER ½*d.*–1*d.* PER UNIT +STANDING CHARGE	
WATTS	No.	%	No.	%
Up to 50	61	13	36	16
Over 50–75	227	48	137	59
Over 75	187	39	58	25
ALL WATTAGES	475	100	231	100
No such room / No answer / No electric light	108		155	

The differences in the sculleries and working kitchens are probably the result of differences in area. Sculleries in flats are much smaller than those in houses. The differences in the other rooms are not wholly explicable in this way as room sizes are not very different. (See Statistical Table 2, Room Size, p. 144).

COMPARISON OF INCOME GROUPS

2. 8. This analysis shows that in all cases the lighting of the higher income groups is better than that of the lower income groups. The proportion having over ½ watt per square foot in the scullery was 52 per cent in the under £187 per annum group, 58 per cent in the £187–£260 per annum group, and 58 per cent in the £260–£520 per annum group. In the kitchen living room the proportions were 41 per cent, 46 per cent, and 52 per cent, and in the sitting room 33 per cent, 41 per cent, and 51 per cent.

ANALYSIS BY COST OF ELECTRICITY

2. 9. The analysis by cost of electricity shows that lighting becomes less adequate as the cost of electricity increases.

The proportion with over ½ watt per square foot was above 60 per cent of those who were paying up to 3*d.* per unit for electricity. It was 54 per cent of those paying between 3*d.* and 4½*d.* per unit and 47 per cent of those paying over 4½*d.* In the kitchen living room the proportions were 52 per cent, 43 per cent, and 32 per cent, and in the sitting room 51 per cent, 34 per cent, and 30 per cent. (Table 3.)

THE INFLUENCE OF THE AREA OF ROOMS

2. 10. In order to test the hypotheses that the adequacy of lighting expressed as watts per square foot was a function mainly of the size of room, rooms were grouped by size to show the proportion of them with different watts per square foot.

This analysis showed quite clearly that the larger the room the greater was the proportion with less than ½ watt per square foot. For example, in sculleries of up to and including 50 square feet only 14 per cent of them had ½ watt per square foot or less. In sculleries of between 51 to 100 square feet the proportion was 49 per cent, with sculleries 101 to 150 square feet the proportion was 79 per cent, and in sculleries larger than this the proportion was, in all cases, over 90 per cent. The same tendency occurs to a lesser degree in the kitchen living room and in the sitting room or parlour. (Table 4.)

TABLE 3

WATTS PER SQUARE FOOT FOR ALL ROOMS

Refers to paragraph 2. 9 Analysis by Cost of Electricity

SCULLERY

WATTS PER SQUARE FOOT	UP TO 3d.		3d.–4½d.		OVER 4½d.		ALL GROUPS	
	No.	%	No.	%	No.	%	No.	%
Up to and including ·50	461	40	164	46	209	53	834	44
·51 to and including 1·00	466	40	144	41	145	36	755	39
1·01 to and including 1·50	144	12	36	10	31	8	211	11
1·51 and over	93	9	10	3	12	3	115	6
TOTAL	1164	100	354	100	397	100	1915	100
No such room	142		33		26		201	
No light and no answer	109		48		55		212	
SAMPLE	1415		435		478		2328	

KITCHEN LIVING ROOM

WATTS PER SQUARE FOOT	UP TO 3½d.		3d.–4½d.		OVER 4½d.		ALL GROUPS	
	No.	%	No.	%	No.	%	No.	%
Up to and including ·50	516	48	198	57	269	68	983	54
·51 to and including 1·00	485	45	133	38	108	27	726	40
1·01 to and including 1·50	48	4	14	4	16	4	78	4
1·51 and over	28	3	5	2	5	1	38	2
TOTAL	1077	100	350	100	398	100	1825	100
No such room	318		75					
No light and no answer	20		10		71		464	
					9		39	
SAMPLE	1415		435		478		2328	

SITTING ROOM

WATTS PER SQUARE FOOT	UP TO 3d.		3d.–4½d.		OVER 4½d.		ALL GROUPS	
	No.	%	No.	%	No.	%	No.	%
Up to and including ·50	439	49	160	66	226	70	825	56
·51 to and including 1·00	404	45	73	30	87	27	564	39
1·01 to and including 1·50	43	5	8	3	8	2	59	4
1·51 and over	11	1	2	—	2	1	15	1
TOTAL	897	100	243	100	323	100	1463	100
No such room	368		113		110		591	
No light and no answer	150		79		45		274	
SAMPLE	1415		435		478		2328	

Cost unclassified=47

TABLE 4

WATTS PER SQUARE FOOT FOR ALL ROOMS

Refers to paragraph 2. 10

Analysis by Area

SCULLERY OR WORKING KITCHEN

WATTS	UP TO AND INCLUDING 50 SQ. FT.		51–100 SQ. FT.		101–150 SQ. FT.		OVER 150 SQ. FT.		NO ANSWER AND DOES NOT APPLY	ALL AREAS	
	No.	%	No.	%	No.	%	No.	%	No.	No.	%
·01– ·50	80	14	524	49	193	79	55	92	—	852	44
·51–1·00	240	42	475	44	50	21	5	8	—	770	40
1·01–1·50	149	26	66	6	1	—	—	—	—	216	11
1·51 and over	104	19	12	1	—	—	—	—	—	116	5
ALL	573	100	1077	100	244	100	60	100	—	1954	100
No answer and does not apply	75		65		6		3		272	421	
SAMPLE	648		1142		250		63		272	2375	

KITCHEN LIVING ROOM

WATTS	UP TO AND INCLUDING 100 SQ. FT.		101–150 SQ. FT.		151–200 SQ. FT.		201 SQ. FT. AND OVER		NO ANSWER AND DOES NOT APPLY	ALL AREAS	
	No.	%	No.	%	No.	%	No.	%	No.	No.	%
·01– ·50	65	19	459	54	324	66	150	91	—	998	54
·51–1·00	198	58	373	44	161	32	12	7	—	744	40
1·01–1·50	50	14	19	2	8	2	2	1	—	79	4
1·51 and over	31	9	6	—	1	—	—	—	—	38	2
ALL	344	100	857	100	494	100	164	100	—	1859	100
No answer and does not apply	3		9		1		1		502	516	
SAMPLE	347		866		495		165		502	2375	

SITTING ROOM OR PARLOUR

WATTS	UP TO AND INCLUDING 100 SQ. FT.		101–150 SQ. FT.		151–200 SQ. FT.		201 SQ. FT. AND OVER		NO ANSWER AND DOES NOT APPLY	ALL AREAS	
	No.	%	No.	%	No.	%	No.	%	No.	No.	%
·01– ·50	55	33	310	55	263	54	213	79	—	841	56
·51–1·00	87	52	221	39	213	44	52	19	—	573	38
1·01–1·50	21	13	25	4	12	2	4	1	—	62	4
1·51 and over	5	2	8	1	1	—	1	—	—	15	1
ALL	168	100	564	100	489	100	270	100	—	1491	100
No answer and does not apply	24		68		22		11		759	884	
SAMPLE	192		632		511		281		759	2375	

CHANGES IN LAMPS SINCE THE WAR

2. 11. Blackout restrictions and fuel economy have caused a considerable number of households to reduce the size of lamps used. This was so in 608 out of 1954 houses in relation to the working kitchen, in 514 out of 1859 houses in relation to the kitchen living room, and in 477 out of 1491 houses in relation to the sitting room.

In order to find out the effect this had on lighting, the cases in which lighting was the same as pre-war was compared with those where the lighting had been reduced. It was found that in all cases a greater proportion of rooms had less than half watt per square foot where the wattage had been reduced since the war. This is shown in detail in the abstract table below :

		WATTS SAME AS PRE-WAR		WATTS LESS THAN PRE-WAR	
		%	Std. Dev.	%	Std. Dev.
Scullery or Working Kitchen	Less than ½ watt per sq. ft.	39	± 1·4	56	± 2·0
	More than ½ " "	61	± 1·4	44	± 2·0
Kitchen Living Room	Less than ½ " "	47	± 1·4	71	± 2·0
	More than ½ " "	53	± 1·4	29	± 2·0
Sitting Room	Less than ½ " "	53	± 1·6	64	± 2·2
	More than ½ " "	47	± 1·6	36	± 2·2

POSITION OF FITTING

2. 12. Our investigators were asked to note whether the fitting was in the ceiling, on a wall bracket, or a movable fitting, and it was found that the fitting was in the ceiling in 98 per cent of sculleries or working kitchens, in 99 per cent of kitchen living rooms, and in 98 per cent of sitting rooms and parlour.

In the case of the second fitting most were movable, the proportions for second fittings were for the kitchen living room, 16 per cent in the ceiling, 16 per cent on a bracket, and 68 per cent movable. In the case of the sitting room or parlour, 9 per cent ceiling, 15 per cent bracket, and 76 per cent movable.

The numbers in the scullery or working kitchen were too small to be analysed.

The proportions having movable fittings were highest in the two higher income groups.

TYPE OF ELECTRIC LIGHT FITTING

2. 13. Our interviewers were asked to classify the electric light fitting according to the main types agreed upon by the Electric Lamp Manufacturers' Association lighting analysis. These were : Direct (1) and (2), Semi-Direct (General), Semi-Indirect and Indirect (see Fig. 66).

This diagram is reproduced from *Electric Illumination*, by W. T. O'Dea, D.Sc., A.M.I.E.E., H.M.S.O. 1937.

The main type of light fitting used in all rooms was the direct, being conical and bell-shaped shades with bulb showing below. Many of these were of vellum open at the top. This accounted for 86 per cent of the first lights in sculleries or working kitchens, 72 per cent in the kitchen living room, and 60 per cent in the sitting room or parlour. The next most popular type was the semi-indirect, in most cases a translucent glass bowl. This type was found in 10 per cent of sculleries or working kitchens, in 14 per cent of kitchen living rooms, and in 21 per cent of sitting rooms or parlours.

The only other type which occurred in large numbers was the general, the totally closed glass fitting which was found in 7 per cent of kitchen living rooms and 7 per cent of sitting rooms or parlours.

7 per cent of sitting rooms or parlours had the indirect type of fitting consisting of opaque bowl beneath the bulb.

COMPARISON OF INCOME GROUPS

2.13.1. The higher income groups in our sample had a greater proportion of fittings which obscured the lamp in their kitchen living rooms and sitting rooms or parlours than the lower income groups. For the purpose of this comparison the general, semi-indirect, and indirect type of fittings have been grouped together and the proportions are :

PROPORTIONS HAVING INDIRECT OR SEMI-INDIRECT FITTINGS	UNDER £187 PER ANNUM	£187–£260 PER ANNUM	£260–£520 PER ANNUM
Kitchen Living Room	21%	23%	31%

The position in the sitting room or parlour was similar, the proportions being :

	UNDER £187 PER ANNUM	£187–£260 PER ANNUM	£260–£520 PER ANNUM
Sitting Room or Parlour	27%	30%	44%

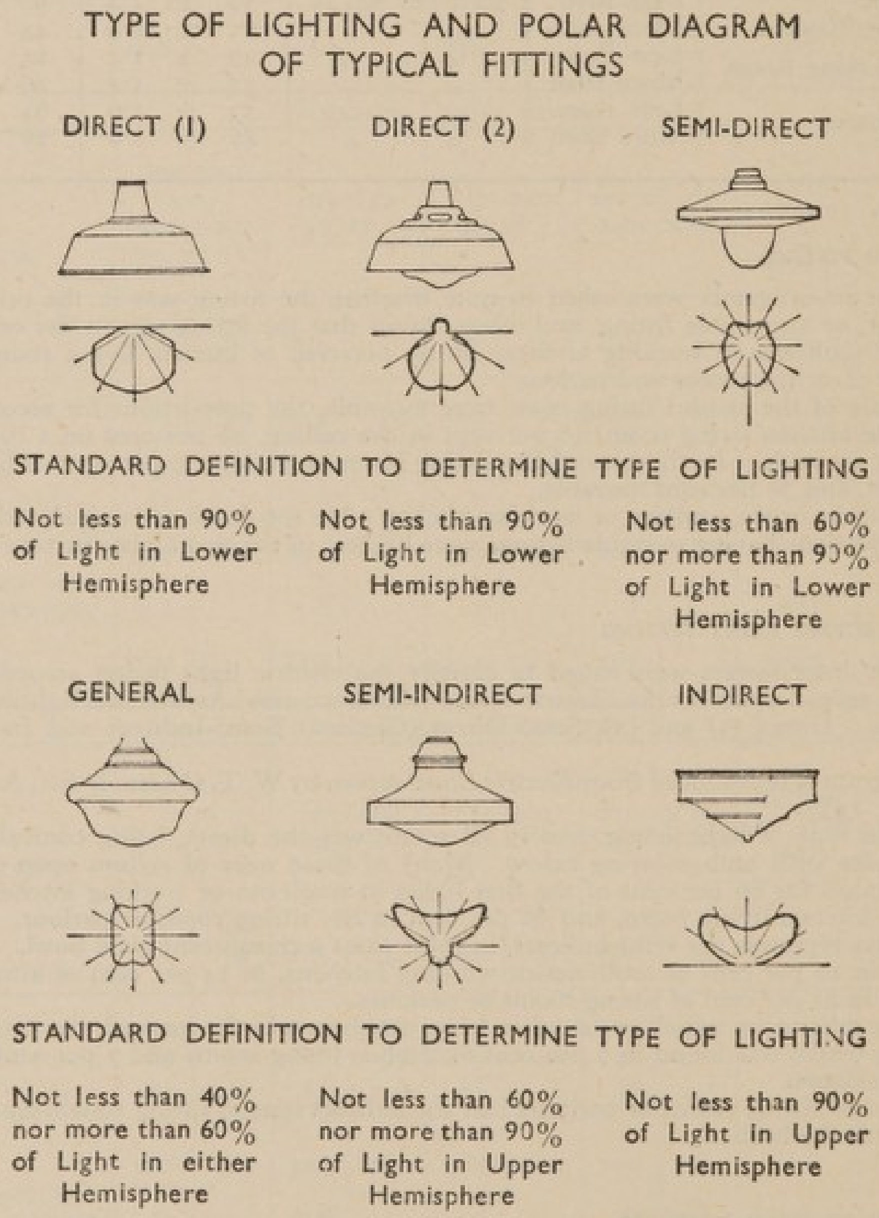


Fig. 66.

THE PROPORTION HAVING MORE THAN ONE LAMP IN THE DIFFERENT INCOME GROUPS

2. 14. This analysis shows that in the higher income groups in all rooms there is a greater proportion having more than one lamp.

	UNDER £187 PER ANNUM %	£187–£260 PER ANNUM %	£260–£520 PER ANNUM %	ALL INCOMES %
Scullery or Working Kitchen	—	1·2	3·1	1·6
Kitchen Living Room	2·5	4·4	8·1	4·8
Sitting Room or Parlour	2·0	7·7	23·2	12·8

UTILIZATION FACTORS

2. 15. 1. The utilization factor is the proportion of the artificial light available which is actually used in any room (reaches the plane of work), that is to say, which is not absorbed by the fitting, or the walls, or the ceiling. This depends upon five factors.

The first is size and shape of the room, that is to say, the distance of the walls from the source of light. The nearer that the walls are, the more light they absorb.

The second is the height of the electric light fitting above the plane of work. The intensity of light at any point diminishes in proportion to the square of the distance from the source.

The third is the colour of the walls, and from this the proportion of the light reaching the walls which is reflected. For our purpose the colour of the walls was divided into two groups, walls fairly dark with a reflection factor of around 25 per cent and a wall fairly light with a reflection factor of about 50 per cent.

The fourth is the colour of the ceiling. Ceilings were graded by our interviewers into two main groups, fairly light with a reflection factor of about 40 per cent and very light with a reflection factor of about 70 per cent These reflection factors were judged on the basis of information in the E.L.M.A. booklet.

The fifth is the type of fitting which has already been described above. Both the direction of the light and the amount absorbed by the fitting are taken into account.

It should be noted that these factors are based on a series of estimations and are therefore only approximate.

Scullery and Working Kitchen. The utilization factors for the scullery and working kitchens fall into three main groups. 9 per cent were between ·3 and ·39, 47 per cent between ·4 and ·49, and 19 per cent between ·5 and ·59.

Kitchen Living Room. The distribution of utilization factors was somewhat wider in the kitchen living room, and in the main the utilization factor was higher. 11 per cent had utilization factors between ·2 and ·29, 9 per cent between ·3 and ·39, 18 per cent between ·4 and ·49, and 57 per cent between ·5 and ·59. This is due entirely to the fact that kitchen living rooms are larger than sculleries or working kitchens.

Sitting Room or Parlour. This distribution was similar to that of the kitchen living room, but the utilization factors were somewhat lower, 15 per cent being between ·2 and ·29, 9 per cent. between ·3 and ·39, 21 per cent between ·4 and ·49, and 47 per cent between ·5 and ·59.

TABLE 5

UTILIZATION FACTORS FOR ALL ROOMS

Refers to paragraph 2. 15. 1

FACTOR	SCULLERY OR WORKING KITCHEN		KITCHEN LIVING ROOM		SITTING ROOM OR PARLOUR	
	No.	%	No.	%	No.	%
·1 –·29	102	5	288	15	351	23
·30–·39	172	9	176	9	144	9
·40–·49	1343	67	335	18	324	21
·50–·69	384	19	1061	58	757	48
TOTAL ANSWERED	2001	100	1860	100	1576	100
No answer	364		505		789	
SAMPLE	2365		2365		2365	

COMPARISON OF HOUSE AND FLAT

2. 15. 2. In the case of the scullery or working kitchen the utilization factor in houses was higher than that in flats. 88 per cent houses had a utilization factor higher than ·4, compared with 74 per cent of flats. In the case of the kitchen living room the utilization factors were almost the same in both houses and flats, there being 75 per cent of the kitchen living rooms in houses with a utilization factor higher than ·4, compared with 76 per cent in flats. On the other hand, the sitting room or parlour in flats had a slightly higher proportion with a high utilization factor, there being only 68 per cent of houses having a utilization factor above ·4, compared with 73 per cent in flats.

These results are probably due to the fact that whereas sculleries are larger in houses than flats there is no great difference in the size of living rooms or parlours. (Statistical Table 2.)

COMPARISON OF PRE-WAR AND POST-WAR DWELLINGS

2. 15. 3. In all cases the pre-war dwelling had a higher utilization factor than post-war dwellings. This is in spite of the fact that post-war houses have larger rooms. The proportions having a utilization factor of more than ·4 are given below :

	PRE-WAR %	POST-WAR %
Scullery or Working Kitchen	87	85
Kitchen Living Room	79	68
Sitting Room or Parlour	70	67

The standard errors of the first pair are of the order of 1 and of the second and third pairs of the order of 1·5.

COMPARISON OF INCOME GROUPS

2. 15. 4. The comparison of income groups shows interesting differences. In the case of sculleries or working kitchens the proportions having a utilization factor of above ·4 are very close in the two lower income groups, being 84 per cent and 86 per cent. In the high group, however, it is 90 per cent. This is probably due to the larger kitchens in the houses of the higher income group.

In the kitchen living room differences are small, the proportions being 78 per cent, 75 per cent, and 71 per cent, the slight decline in the higher income groups being probably due to the higher proportion having light fittings which obscure the lamp. These are found in the following proportions in the three income groups, 21 per cent, 23 per cent, and 31 per cent.

In the sitting room or parlour, however, this tendency is much more marked. The proportions having a higher utilization factor than ·4 were 72 per cent in the lowest income group, 71 per cent in the next income group, and 65 per cent in the highest income group—in spite of the larger rooms found in the higher income groups. The proportions having a fitting obscuring the lamp in the sitting room or parlour were as follows :

UNDER £187 PER ANNUM	£187–£260 PER ANNUM	£260–£520 PER ANNUM
27%	30%	44%

These proportions refer only to the first light.

UTILIZATION FACTOR IN RELATION TO ROOM AREA

2. 15. 5. This analysis shows the considerable importance of room area in determining the utilization factor. In the case of the scullery or working kitchen the proportions of rooms having a utilization factor above ·5 were as follows :

	%
Room area up to 50 sq. ft.	7
" " 51–100 "	14
" " 101–150 "	57

In the case of the kitchen living room a similar tendency can be seen, although in the case of one size of room the trend is interrupted :

	%
Room area 51–100 sq. ft.	30
„ „ 101–150 „	65
„ „ 151–200 „	59
„ „ 201–250 „	72

The sitting room or parlour also showed a similar trend, the proportions having a utilization factor above ·5 were as follows :

	%
Room area 51–100 sq. ft.	33
„ „ 101–150 „	50
„ „ 151–200 „	50
„ „ 201–250 „	51

The consistency in the results of the larger rooms is due, in some cases, to the fact that two lamps were employed. This has the effect of reducing the utilization factor, since these are not placed in the centre of the room but are spaced and therefore come nearer to the walls.

LIGHT-METER READINGS

2. 16. 1. Our investigators measured with a light-meter the amount of light in foot-candles at a number of points in the kitchen or scullery, in the kitchen living room, and in the sitting room.

In the case of the observations made in the sink, on the cooker, on the scullery table and on the kitchen living room table two readings were taken. The first was with the meter unshadowed and the second with the housewife in the position where she normally stood when working.

It will be seen that at the working positions in the scullery very few families have as much light as 5 foot-candles either " unshadowed " or " as used." On the kitchen living room table a small proportion had this amount of light, and a larger proportion in the kitchen living room by the fire and in the sitting room by the fire. (Table 6.)

OBSERVATIONS IN THE SCULLERY OR KITCHEN

2. 16. 2. *The Kitchen Sink.* It will be seen from the abstract below that more than half of kitchen sinks had 1 foot-candle or less unshadowed and nearly three-quarters 1 foot-candle or less as used.

FOOT-CANDLES	UNSHADOWED %	AS USED %
Up to and including 1 foot-candle	54	81
Over 1 and up to 2 foot-candles	23	11
„ 2 foot-candles	23	8

The standard deviations of these percentages are of the order of 1 or less.

Cooker. 45 per cent of the cookers had an illumination of 1 foot-candle or less unshadowed and 76 per cent had an illumination of 1 foot-candle or less when the housewife was in the working position.

Scullery Table. The scullery table was better lighted than either the cooker or the sink, due no doubt to the fact that the housewife has some choice in the placing of her table, whereas there is no choice about the sink or the cooker. A little over one-third of scullery tables had 1 foot-candle or less unshadowed and about two-thirds had 1 foot-candle or less as used ; this showed that even though housewives had some choice in the placing of their kitchen table they were unable to avoid getting in their own light when working at it.

FOOT-CANDLES	UNSHADOWED %	AS USED %
Up to and including 1 foot-candle	37	62
Over 1 and up to 2 foot-candles	27	18
„ 2 foot-candles	36	20

The standard deviations of these percentages are of the order of 1 or less.

Refers to paragraphs 2. 16. 1
and 2. 16. 2

TABLE 6

METER READINGS

FOOT-CANDLES	SINK				COOKER				SCULLERY TABLE				KITCHEN LIVING ROOM TABLE				5 FT. FROM KITCHEN LIVING ROOM FIRE		5 FT. FROM SITTING ROOM FIRE	
	Un-shadowed		As Used		Un-shadowed		As Used		Un-shadowed		As Used		Un-shadowed		As Used		Un-shadowed		Un-shadowed	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 1 foot-candle	1115	54	1650	81	942	45	1603	76	635	37	1063	62	153	22	275	40	118	8	46	5
Over 1 up to 2	469	23	224	11	547	26	268	13	455	27	317	18	66	10	86	12	90	6	81	9
Over 2 up to 3	215	11	87	4	306	15	122	6	260	15	147	9	78	11	92	14	185	12	112	13
Over 3 up to 4	137	7	50	3	166	8	70	3	192	11	108	6	128	19	95	14	281	19	148	17
Over 4	107	5	32	2	141	7	39	2	175	10	82	5	261	38	138	20	810	55	484	56
ALL READINGS	2043	100	2043	100	2102	100	2102	100	1717	100	1717	100	686	100	686	100	1484	100	871	100
No such room	—		—		—		—		202		202		471		471		471		604	
No answer	332		332		273		273		456		456		1218		1218		420		900	
SAMPLE	2375		2375		2375		2375		2375		2375		2375		2375		2375		2375	

Unclassified=9

Kitchen Living Room Table. The kitchen living room table was generally much better lighted than the scullery table, as will be seen from the following abstract:

FOOT-CANDLES	UNSHADOWED %	AS USED %
Up to and including 1 foot-candle	32	40
Over 1 and up to 2 foot-candles	10	12
,, 2 foot-candles	68	48

The standard deviations of these percentages are of the order of 1 or less.

5 ft. from the Kitchen Living Room Fire, 3 ft. from the Floor. In this position of the room light was measured unshadowed only and the illumination was somewhat better than in any other position in kitchen living rooms or sculleries. In only 8 per cent of the observations was the meter reading less than 1 foot-candle. (Table 6.)

5 ft. from the Sitting Room Fire. Illumination in this position was the best of any of those measured, only 5 per cent having 1 foot-candle or less. (Table 6.)

COMPARISON OF HOUSES AND FLATS

2. 16. 3. Comparison of the meter readings taken in houses and flats show that in the "unshadowed" readings the flat is better lighted at the sink, cooker, and on the scullery table; the proportions of flats and houses having a reading of 1 foot-candle or less were as follows:

	SINK		COOKER		SCULLERY TABLE	
	Unshadowed	As Used	Unshadowed	As Used	Unshadowed	As Used
	% Std. Dev.	% Std. Dev.	% Std. Dev.	% Std. Dev.	% Std. Dev.	% Std. Dev.
House	56 ± 1·2	80 ± 1·0	46 ± 1·2	76 ± 1·0	37 ± 1·2	63 ± 1·2
Flat	47 ± 2·7	83 ± 2·1	38 ± 2·6	78 ± 2·3	35 ± 3·1	58 ± 3·2

This is perhaps due to the fact that sculleries and working kitchens are smaller in flats than in houses, so that these places are grouped nearer to the lamp.

On the other hand, it will be seen that this advantage is lost in the case of the sink and cooker when the meter reading is taken with the housewife in the working position, again possibly due to the fact that the sculleries or kitchens of flats are smaller than those of houses, there being consequently less room for manœuvre.

In the case of the kitchen living room table the superiority of the flat was marked in both the "unshadowed" and the "as used" meter readings: the proportions were 25 per cent of houses having 1 foot-candle or less on the kitchen living room table "unshadowed" compared with 11 per cent of flats, and 42 per cent having 1 foot-candle or less "as used" compared with 31 per cent of flats.

The readings taken 5 ft. from the kitchen living room fire "unshadowed" and 5 ft. from the sitting room fire "unshadowed" showed a superiority for houses in both cases. Only 7 per cent of houses had 1 foot-candle or less, compared with 14 per cent of flats in the case of the kitchen, and 4 per cent compared with 11 per cent in the case of the sitting room. In this analysis emphasis has been placed on the bad lighting rather than the good.

PRE-WAR AND POST-WAR HOUSES COMPARED

2. 16. 4. This comparison showed that there was very little difference between pre-war and post-war houses in the light-meter readings in the principal working positions of the downstairs rooms. If anything there was a slight superiority of the post-war house, particularly in the "as used" positions on the sink and cooker.

COMPARISON OF INCOME GROUPS

2. 16. 5. The analysis by watts per square foot showed a marked superiority of the illumination in the rooms of the higher income group. This superiority is shown by the analysis of meter readings, but to a lesser degree, and in one case, that of the kitchen living room table, the kitchen living rooms of the poorer class are better illuminated than the upper classes. This is due no doubt to the fact that the kitchen living room has a different function in the houses of families under £260 per annum than in the houses of families with incomes between £260–£520 per annum.

In the case of the analysis of the kitchen living room fire and the sitting room fire there is very little difference between the income groups, as the following abstracts show:

PROPORTION HAVING 1 FOOT-CANDLE OR LESS IN THE FOLLOWING POSITIONS

	UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM	
	Un-shadowed Std. Dev. %	As Used Std. Dev. %	Un-shadowed Std. Dev. %	As Used Std. Dev. %	Un-shadowed Std. Dev. %	As Used Std. Dev. %
Sink	58 ± 2·0	84 ± 1·5	56 ± 2·0	83 ± 1·5	49 ± 2·0	76 ± 1·8
Cooker	49 ± 2·0	80 ± 1·6	46 ± 2·0	80 ± 1·4	40 ± 1·9	76 ± 1·8
Scullery Table	44 ± 2·3	66 ± 2·4	39 ± 2·3	64 ± 2·0	30 ± 2·3	55 ± 2·1
Kitchen Living Room Table	16 ± 2·3	35 ± 3·0	19 ± 2·3	39 ± 3·0	36 ± 3·0	49 ± 3·2

It will be seen that the effect of shadowing is very important in all cases and somewhat reduces the superiority of the lighting of the higher income group.

In the following abstract the proportions having less than 5 foot-candles in the kitchen living room 5 ft. from the fire and in the sitting room 5 ft. from the fire are shown. A higher value has been taken because these rooms are better illuminated.

INCOME GROUPS	KITCHEN LIVING ROOM FIRE	SITTING-ROOM FIRE
	Under 5 foot-candles	Under 5 foot-candles
	% Std. Dev.	% Std. Dev.
Under £187	63 ± 2·0	69 ± 3·5
£187–260	60 ± 2·0	63 ± 2·7
£260–520	54 ± 2·5	53 ± 2·7

ANALYSIS BY COST OF ELECTRICITY

2. 16. 6. In the analysis of illumination by watts per square foot the effect of the cost of electricity was quite marked, but in this analysis of light-meter readings there is no such clear falling-off in the lighting where the cost of electricity is higher. As in the case of the previous analysis this is possibly the result of the fact that the main positions where lights were measured are grouped at a point fairly near to the centre of illumination, whereas watts per square foot are an indication of the illumination of the whole surface of the room. That is to say, the one is an average of the light and the other is the light at a few particular points insufficient in themselves to be representative of the whole situation. The following abstract shows the proportion in each room having one foot-candle or less at each point:

	UP TO 3*d.*		3*d.*–4½*d.*		OVER 4½*d.*	
	Un-shadowed %	As Used %	Un-shadowed %	As Used %	Un-shadowed %	As Used %
Sink	56	72	51	83	57	81
Cooker	43	77	41	80	44	74
Scullery Table	39	65	29	58	40	59
Kitchen Living Room Table	22	42	14	27	31	48
Kitchen Living Room Fire	—	7	—	11	—	7
Sitting Room Fire	—	5	—	6	—	9

HOUSEWIFE'S OPINION OF HER ABILITY TO SEE ANALYSED IN RELATION TO LIGHT-METER READINGS

2. 16. 7. In every category, namely housewives who could see well, all right, or badly, cases were found where there were meter readings from 0 to 12 foot-candles showing that ability to see is a subjective as well as an objective matter. However, if an average is taken it is found that the housewives who say they can see well have better lighting than those who can see all right, and those who say they can see all right have better lighting than those who can see badly. The following abstract table shows the position :

The readings in each case are " as used."

	AVERAGE READING IN FOOT-CANDLES		
	Well	All Right	Badly
Cooking	1·7	1·3	1·2
Washing-up	3·4	1·3	1·1
Preparing food	2·3	1·8	1·4
Reading and Sewing in Kitchen Living Room	6·1	5·0	3·4
Reading and Sewing in Sitting Room or Parlour	5·8	5·2	4·0

The standard deviations on these numbers are of the order of ·1, so that all the differences except perhaps those between "all right" and "badly" for cooking and washing-up are significant.

CONCLUSION

2. 17. 1. *Watts available.* The most striking point of this analysis is the small wattages found in the scullery or working kitchen where most of the detailed household tasks are done ; almost all had less than 75 watts and a third had less than 25 watts. The other rooms had more powerful lamps, but, of course, the rooms were larger and in many cases the fittings absorbed some of the light.

The size of lamps was significantly larger in the higher income groups.

2. 17. 2. *Watts Analysed in relation to Housewives' Views about their Ability to See.* This analysis shows that although at every point there are housewives who say they can see well in spite of the very small amount of light, in general, the higher the watts the greater is the proportion who are able to see well.

2. 17. 3. *Watts per Square Foot.* This analysis showed that 44 per cent of scullery or working kitchens, 54 per cent of kitchen living rooms, and 56 per cent of sitting rooms had less than half a watt per square foot.

The analysis taking account of size of rooms showed that householders often failed to use more light in larger rooms.

2. 17. 4. *Changes in Lamps since the War.* About one-third of households are using lamps of less power than before the war. This has produced a marked difference in their lighting measured in watts per square foot.

2. 17. 5. *Fittings.* The main type of fitting used was the direct fitting, which accounted for two-thirds of the fittings in the sitting room or parlour and more in the other rooms. The type of fitting which obscured the lamp was found more in the sitting rooms or parlours than elsewhere, and more in the higher income groups than in the lower. The proportions having more than one lamp was much higher in the highest income group than in the two others.

2. 17. 6. *Utilization Factor.* In the scullery and working kitchen, two-thirds of dwellings had a utilization factor higher than ·4, in the kitchen living room the proportion was four-fifths, and in the sitting room or parlour the proportion was about three-quarters. The falling off in the sitting room or parlour is probably due to the use of fittings which obscure the lamp, as there were no very great differences in the proportions having light and dark walls.

2. 17. 7. *Light-Meter Readings.* The most striking feature of the tests made with the light meter was the fact that of the main working positions of the scullery or kitchen, only in the case of the kitchen living room table and the fireplace position was there a considerable proportion of dwellings with four foot-candles or more. At the sink and cooker a very large proportion of housewives had less than one foot-candle, and the proportion having this amount of light was quite large at the scullery table. The lighting of the sitting room fire position was much better, over half having more than four foot-candles.

There were no very great differences between houses and flats or between pre-war and post-war dwellings, nor was there any marked differences between the income groups.

The analysis by cost of electricity did not show the same tendency as the analysis of watts per square foot, probably due to the fact that these working positions are very near the centre of light.

The average meter readings at each of the main working positions showed that the housewives who could see well had more light than those who said they could see all right or badly, although within each group there was a wide range in the amount of light available.

Section II

3. ARTIFICIAL LIGHTING

3. 1. The housewife was asked whether she was able to see well, all right, or badly by artificial light when she was doing the following jobs :

Washing-up
Preparing Food
Cooking
Reading or Sewing in the Kitchen Living Room
Reading or Sewing in the Sitting Room or Parlour

and whether she considered the children were able to see well when they were doing their homework in the kitchen living room, and when they were doing their homework in the sitting room.

From the answers given it appears that housewives were much better satisfied with the lighting in their kitchen living room and parlour than in their kitchen or scullery. (Refers to Table 7.)

WASHING-UP

3. 2. 36 per cent of housewives said that they could see well when washing-up, 47 per cent said that they could see all right, and 18 per cent said that they could see badly. (Refers to Table 7.)

PREPARING FOOD

3. 3. The analysis of the answers about preparing food was similar to that about washing-up, the proportions being 38 per cent able to see well, 49 per cent able to see all right, and 13 per cent who saw badly. (Refers to Table 7.)

COOKING

3. 4. The analysis of the answers about cooking was similar to those of the two previous analyses, the proportions being 37 per cent able to see well, 46 per cent able to see all right, and 16 per cent who saw badly. (Refers to Table 7.)

READING OR SEWING IN KITCHEN LIVING ROOM

3. 5. This analysis showed that housewives considered lighting in the kitchen living room rather better than lighting for washing-up, preparing food, or cooking ; 47 per cent said that they saw well, 46 per cent said that they could see all right, and 6 per cent that they could see badly. (Refers to Table 7.)

READING OR SEWING IN SITTING ROOM OR PARLOUR

3. 6. This analysis shows a slight improvement over the previous one, the proportions able to see well were 54 per cent, all right 41 per cent, and badly 5 per cent. (Refers to Table 7.)

FOR CHILDREN TO SEE DOING HOMEWORK IN THE KITCHEN LIVING ROOM

3. 7. As in the other analysis of the lighting in the kitchen living room the housewife considered it to be satisfactory ; 46 per cent said that the children could see well, 52 per cent said that the children could see all right, and only 3 per cent thought that children saw badly. (Refers to Table 7.)

FOR CHILDREN TO SEE DOING HOMEWORK IN THE SITTING ROOM OR PARLOUR

3. 8. As in the case of the housewife seeing, this analysis showed that the lighting of the sitting room or parlour was more satisfactory than any other room in the house, and more satisfactory than the kitchen living room for the children to do their homework. The proportions of children able to see well was 51 per cent, 45 per cent could see all right, and only 4 per cent saw badly. (Refers to Table 7.)

TABLE 7

HOW WELL HOUSEWIVES SAY THEY ARE ABLE TO SEE BY ARTIFICIAL LIGHT WHEN DOING CERTAIN JOBS

	WELL %	STD. DEV.	ALL RIGHT %	STD. DEV.	BADLY %	STD. DEV.
Washing-up	36	± 1·0	47	± 1·0	18	± ·8
Preparing Food	38	± 1·0	49	± 1·1	13	± ·7
Cooking	37	± 1·0	47	± 1·0	16	± ·8
Reading or Sewing in Kitchen Living Room	47	± 1·2	46	± 1·2	6	± ·5
Reading or Sewing in Sitting Room or Parlour	54	± 1·3	41	± 1·2	5	± ·5
Children doing Homework in Kitchen Living Room	45	± 2·4	52	± 2·6	3	± 1·0
Children doing Homework in Sitting Room or Parlour	51	± 3·1	45	± 2·9	4	± 1·3

COMPARISON OF HOUSES AND FLATS

3. 9. The lighting in flats appears to be significantly better than the lighting in houses for the main jobs which are done in the scullery or working kitchen; for example, the proportion who say they see badly when washing-up is 13 per cent ± 1·7 in flats, compared with 19 per cent ± ·9 in houses. In the case of preparing food the proportions are 6 per cent ± 1·2 and 14 per cent ± ·8, and in the case of cooking 14 per cent ± 1·8 and 17 per cent ± ·8.

In the kitchen living room and sitting room the lighting for reading or sewing is, however, better in houses. There is not much difference in the proportions who see badly, but the proportions who say they see well are rather higher in houses. In the kitchen living room the proportions are 49 per cent ± 1·2 compared with 37 per cent ± 2·9, and in the sitting room or parlour 55 per cent ± 1·3 compared with 50 per cent ± 3·5. The same differences occur in the answers about children doing homework in these two rooms.

COMPARISON OF PRE-WAR AND POST-WAR DWELLINGS

3. 10. The post-war dwellings have a slightly higher proportion of housewives who thought they could see well when working in the kitchen than the pre-war. The differences were small. In the kitchen living room, and sitting room, and parlour the proportion of housewives who said that they could see well when reading or sewing was considerably higher in the post-war houses than in the pre-war houses. The proportions for the kitchen living room were 52 per cent compared with 44 per cent, and for the sitting room or parlour 58 per cent compared with 51 per cent.

The proportion of children of whom their mothers said that they could see well whilst doing their homework was similarly greater in post-war dwellings.

COMPARISON OF INCOME GROUPS

3. 11. In this analysis a very clear trend is shown from the lowest income group to the highest. The lowest income group has the smallest proportion who see well, the middle income group a larger proportion, and the highest income group the largest proportion. The differences are significant in all the kitchen tasks; for example, in preparing food the proportion who could see well is 32 per cent ± 1·7 in the £187 per annum group, 36 per cent ± 1·5 in the £187–£260 per annum group, and 47 per cent ± 1·8 in the £260–£520 per annum group.

The difference is even greater in the kitchen living room, where the proportions are 42 per cent ± 1·9, 48 per cent ± 1·9, and 54 per cent ± 2·1, and in the sitting room or parlour 49 per cent ± 2·9, 51 per cent ± 2·1, and 59 per cent ± 1·9. In the case of children doing their homework the same trend was apparent in the kitchen living room. In this analysis, however, the samples were rather small.

ANALYSIS BY COST OF ELECTRICITY

3. 12. The households in the sample were divided, according to the cost of electricity per unit, into three groups: those who paid up to 3*d*., those who paid from 3*d*. and up to 4½*d*., and those who paid over 4½*d*. There were only very small differences between the proportions who could see well, all right, or badly whilst doing the different tasks in the home. The differences in the analysis are by no means clear-cut, but taken as a whole they indicate

that the proportion who see well is, in general, a little higher in the households where electricity is cheapest, and the proportion who see badly is somewhat higher in the two groups which have the dearer electricity. In the case of washing-up, preparing food, and cooking, the highest proportion who could see badly is in the middle group.

CONCLUSION

3. 13. This section has been analysed on the basis of a rating of lighting on a simple three-point scale; the division " well " indicating positive satisfaction, " all right " indicating a neutral attitude towards the lighting, and " badly " meaning positive dissatisfaction. The fact that there are differences about the satisfaction with the lighting at different points and the fact that there is not a normal distribution of answers around the three points, suggests that this scale has given meaningful answers.

The main conclusions are that for the jobs which have to be done in the scullery over one-third see well, and for the jobs that have to be done in the living room or parlour about one-half see well, between two-fifths and one-half see all right in all places, and one-half to one-fifth see badly in the scullery, and about one-twentieth in the kitchen or parlour.

Reference to Section I will show the relationship of watts per square foot as a measure of artificial light to housewives' views about their lighting.

There was a significantly larger proportion of housewives who said they could see well in the groups with more watts per square foot than in the groups with less, although there was a wide range of watts per square foot within each opinion group. In the same way the housewife's opinion about her lighting correlated with the average amount of light available in foot-candles.

The detailed analyses of this question showed that satisfaction with artificial lighting was greater in flats than in houses, in post-war dwellings than in pre-war dwellings, and that the satisfaction with electric lighting was highest in the highest income group, lower in the next, and lowest in the lowest income group.

Section III

4. OBSERVATIONS WITH MIRROR

4. 1. It is possible to discover whether or not there is direct daylight at any point in a room by placing a small mirror upon the spot and seeing if it is possible to obtain a reflection of the sky in the mirror.

This observation was made in some of the main working positions in the house, they were:

The Centre of the bottom of the Sink.
The Work-table in the Kitchen.
The top of the Cooker.
And at a point 3 ft. above the floor, 5 ft. from the Parlour fireplace.

CENTRE OF THE BOTTOM OF THE SINK

4. 2. In 88 per cent of all dwellings there was a visible sky from the centre of the bottom of the sink, in 10 per cent sky was not visible, and in 2 per cent of the dwellings no observation was taken.

THE WORK-TABLE IN THE KITCHEN

4. 3. In 83 per cent of all dwellings sky was visible from the top of the kitchen table, in 15 per cent there was no sky visible, and in 1 per cent no observation was taken.

TOP OF THE COOKER

4. 4. The lighting of the top of the cooker was worse than that of the other two working positions in the kitchen ; 75 per cent had sky visible from the top of the cooker, 24 per cent had not, and in 1 per cent of the kitchens no observation was taken.

3 FT. ABOVE THE FLOOR, 5 FT. FROM THE PARLOUR FIREPLACE

4. 5. This is taken to be the usual place where reading and sewing are done. The lighting here was rather better than the kitchen work-places, 89 per cent of dwellings having sky visible at this point, 8 per cent having no sky visible, and in 2 per cent no observations were taken.

COMPARISON OF HOUSES AND FLATS

4. 6. There is no very great difference between the houses and flats in the sample, although at each of the points in the kitchen the flats have a slightly larger proportion with sky visible than houses. On the other hand, in the case of the parlour, the house has a slightly greater proportion of cases where there is visible sky in the parlour position.

COMPARISON OF PRE-WAR AND POST-WAR DWELLINGS

4. 7. In all cases the post-war dwelling is markedly superior to the pre-war, the proportions having clear sky at the three points in the kitchen are as follows :

PROPORTION HAVING SKY VISIBLE AT	PRE-WAR		POST-WAR	
	%	Std. Dev.	%	Std. Dev.
Centre of bottom of Sink	84	± 1·0	93	± ·8
Work-table in Kitchen	79	± 1·1	89	± ·9
Top of Cooker	69	± 1·2	82	± 1·2

This superiority of the post-war dwelling is also found in the parlour though to a less extent, the proportions being 86 per cent with visible sky in pre-war dwellings, compared with 93 per cent in post-war dwellings.

COMPARISON OF INCOME GROUPS

4. 8. In every case this analysis shows that ascending through the income scale the proportion of dwellings having sky visible from the main working positions increases and the difference in some cases, between the lowest and the highest income group, is quite large. The proportions are given below :

PROPORTION HAVING SKY VISIBLE AT	UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM	
	%	Std. Dev.	%	Std. Dev.	%	Std. Dev.
Centre of bottom of Sink	83	± 1·3	89	± 1·0	91	± 1·0
Work-table in Kitchen	78	± 1·5	84	± 1·2	88	± 1·2
Top of Cooker	67	± 1·7	77	± 1·4	81	± 1·4
3ft. above floor, 5 ft. from Parlour fireplace	85	± 1·3	90	± 1·0	92	± 1·0

COMPARISON OF THE REGIONS

4. 9. In the case of the main working positions in the kitchen, Scotland and the North are superior in every case to the other regions, and London is in every case the worst. In the parlour position the North, the South, South-West and Wales, and the Midlands all have a higher proportion with sky visible than London.

PROPORTION HAVING SKY VISIBLE AT	SCOTLAND %	NORTH %	MIDLANDS %	S. AND S.W. %	LONDON %
Centre of bottom of Sink	96	93	86	86	80
Work-table in Kitchen	87	94	82	77	76
Top of Cooker	82	87	70	72	64
3 ft. above floor, 5 ft. from Parlour fireplace	88	98	90	91	74

CONCLUSION

4. 10. This analysis shows that there was direct daylight at the main working positions in between three-quarters and nine-tenths of all dwellings.

The detailed analyses showed that post-war dwellings were better in this respect than pre-war, and that the dwellings of the higher income groups were better than those of the lower. London was markedly inferior to the other regions.

It should be noted that this analysis takes no account of shadowing, which occurs in some cases when the housewife is working.

Section IV

5. DAYLIGHTING

5. 1. This section follows exactly the section on artificial lighting except that the questions were asked about daylight.

The first thing which is notable about this analysis is that the proportion of housewives who could see well whilst doing their housework is much higher by daylight than by artificial light: for example, 67 per cent say that they see well whilst washing-up by daylight compared with 36 per cent by artificial light, 63 per cent whilst preparing food by daylight compared with 38 per cent by artificial light, 60 per cent whilst cooking by daylight compared with 37 per cent by artificial light. This is in itself an index of dissatisfaction with artificial lighting. Similar differences, though less in extent, exist in the case of the kitchen living room and sitting room or parlour.

Unlike the analysis by artificial light, there is no very great difference between the proportion who say they are able to see well whilst doing their jobs in the kitchen or scullery and the proportion who say they are able to see well in the kitchen living room and sitting room or parlour. (Refers to Table 8.)

Table 8

How Well Housewives say They can See by Daylight when doing Certain Jobs

JOB	WELL %	STD. DEV.	ALL RIGHT %	STD. DEV.	BADLY %	STD. DEV.
Washing-up	67	± 1·0	28	± ·8	5	± ·4
Preparing Food	63	± 1·0	31	± ·9	6	± ·4
Cooking	60	± 1·0	30	± ·9	10	± ·6
Reading or Sewing in Kitchen Living Room	62	± 1·1	31	± 1·0	7	± ·6
Reading or Sewing in Sitting Room or Parlour	70	± 1·0	27	± ·9	3	± ·4
Children doing Homework in Kitchen Living Room	59	± 1·0	35	± 1·0	6	± ·5
Children doing Homework in Sitting Room or Parlour	69	± 2·7	29	± 2·5	2	± ·9

COMPARISON OF HOUSES AND FLATS

5. 2. In all cases, except in the analysis of how well children are able to see whilst doing their homework, the daylight of houses is considered better than that of flats, although the difference is not large; for example, in the case of washing-up 67 per cent ± 1·0 of housewives living in houses say they are able to see well compared with 62 per cent ± 2·3 of those living in flats. In the case of reading or sewing in the kitchen living room 63 per cent ± 1·1 of the housewives living in houses say they are able to see well compared with 53 per cent of those living in flats.

COMPARISON OF PRE-WAR AND POST-WAR DWELLINGS

5. 3. This analysis shows a very considerable superiority of the daylighting in post-war dwellings. In every case the proportion of housewives who say they can see well is very much greater; for example, in the case of washing-up 79 per cent ± 1·3 of housewives living in post-war dwellings say they see well compared with 56 per cent ± 1·3 of those living in pre-war dwellings. In the case of reading or sewing in kitchen living room the proportion is 76 per cent ± 1·5 compared with 52 per cent ± 1·4. In all the other analyses similar differences occur. (Refers to Table 9.)

TABLE 9

HOW WELL HOUSEWIVES SAY THEY ARE ABLE TO SEE BY DAYLIGHT WHEN DOING CERTAIN JOBS. ANALYSED BY AGE OF DWELLING

JOB	PRE-WAR			POST-WAR		
	Well Std. Dev. %	All Right Std. Dev. %	Badly Std. Dev. %	Well Std. Dev. %	All Right Std. Dev. %	Badly Std. Dev. %
Washing-up	56 ± 1·3	35 ± 1·2	9 ± ·9	79 ± 1·4	19 ± 1·3	2 ± ·5
Preparing Food	53 ± 1·3	39 ± 1·2	8 ± ·8	75 ± 1·3	21 ± 1·3	4 ± ·6
Cooking	50 ± 1·4	36 ± 1·2	14 ± 1·0	73 ± 1·3	22 ± 1·3	5 ± ·6
Reading or Sewing in Kitchen Living Room	52 ± 1·5	37 ± 1·4	11 ± ·9	76 ± 1·5	22 ± 1·5	2 ± ·6
Reading or Sewing in Sitting Room or Parlour	61 ± 1·6	34 ± 1·5	5 ± ·7	79 ± 1·6	20 ± 1·5	1 ± ·5
Children doing Homework in Kitchen Living Room	47 ± 3·5	43 ± 3·5	10 ± 3·1	71 ± 3·1	27 ± 3·1	2 ± 1·1
Children doing Homework in Sitting Room or Parlour	60 ± 4·6	35 ± 4·5	5 ± 2·2	76 ± 3·7	24 ± 3·7	— —

COMPARISON OF INCOME GROUPS

5. 4. In each of the analyses by income groups there is a similar significant trend from the lowest group to the highest. The proportions of housewives who are able to see well when washing-up are 60 per cent of the lowest income group, 66 per cent of the middle income group, and 72 per cent of the highest income group. In the case of reading or sewing in the kitchen living room the proportions are 53 per cent, 62 per cent, and 73 per cent. (Refers to Table 10.)

ANALYSIS BY REGION

5. 5. The analysis shows a clear trend from good in the North to poor in the South if the figures for London are excluded.

It is difficult to account for this except in terms of atmospheric pollution since the length of the solar day at this time of year is almost equal through the whole country.

There is no correlation between the proportions seeing well and those having direct daylight.

The following abstract tables show the proportions who can see well when doing various jobs and the proportions having direct daylight.

PROPORTION SEEING WELL	SCOTLAND %	NORTH %	MIDLANDS %	S. AND S.W. %	LONDON %
Washing-up	53	59	74	77	63
Preparing Food	51	57	73	69	58
Cooking	49	55	68	65	57
Reading or Sewing in Kitchen Living Room	52	57	67	69	51
Reading or Sewing in Sitting Room or Parlour	48	59	75	81	65
PROPORTION OF HOUSEHOLDS WITH VISIBLE SKY AT THE					
Centre bottom of Sink	96	93	86	86	80
Work-table in Kitchen	87	94	82	77	76
Top of Cooker	82	87	70	72	64
3 ft. above floor, 5 ft. from Parlour fireplace	88	98	90	91	74
SAMPLE	309	571	568	540	387

TABLE 10

HOW WELL HOUSEWIVES SAY THEY ARE ABLE TO SEE BY DAYLIGHT WHEN DOING CERTAIN JOBS.
ANALYSED BY INCOME GROUP

	UNDER £187 PER ANNUM			£187–£260 PER ANNUM			£260–£520 PER ANNUM		
	Well Std. Dev. %	All Right Std. Dev. %	Badly Std. Dev. %	Well Std. Dev. %	All Right Std. Dev. %	Badly Std. Dev. %	Well Std. Dev. %	All Right Std. Dev. %	Badly Std. Dev. %
Washing-up	60 ± 1·8	32 ± 1·7	7 ± ·9	66 ± 1·5	29 ± 1·5	5 ± ·7	72 ± 1·5	22 ± 1·5	5 ± ·8
Preparing Food	55 ± 1·8	36 ± 1·7	9 ± 1·1	62 ± 1·6	31 ± 1·5	6 ± ·7	70 ± 1·5	25 ± 1·5	5 ± ·8
Cooking	52 ± 1·8	33 ± 1·7	14 ± 1·3	61 ± 1·6	29 ± 1·5	9 ± ·9	66 ± 1·5	26 ± 1·5	7 ± ·8
Reading or Sewing in Kitchen Living Room	53 ± 1·9	38 ± 1·8	10 ± 1·1	62 ± 1·8	31 ± 1·7	7 ± ·9	73 ± 1·9	22 ± 1·8	5 ± 1·0
Reading or Sewing in Sitting Room or Parlour	60 ± 2·7	34 ± 2·5	7 ± 1·0	68 ± 1·9	29 ± 1·8	3 ± ·6	74 ± 1·6	23 ± 1·5	3 ± ·6
Children doing Homework in Kitchen Living Room	53 ± 5·0	35 ± 4·6	11 ± 3·1	56 ± 3·5	39 ± 3·4	6 ± 1·6	70 ± 4·5	28 ± 4·4	2 ± 1·6
Children doing Homework in Sitting Room or Parlour	59 ± 7·6	34 ± 7·4	7 ± 4·0	68 ± 4·4	28 ± 4·3	4 ± 1·9	72 ± 4·3	28 ± 4·2	— —

CONCLUSION

5. 6. Daylighting is significantly more satisfactory than artificial lighting, about two-thirds saying they see well compared with one-third.

There were no very great differences between house and flat, but the analysis by age of dwelling showed that the post-war dwelling was superior to the pre-war. The analysis by income showed the same trend as that of the artificial lighting analysis, that lighting is better in the dwellings of the higher income groups.

SECTION V

6. THE USE OF ELECTRIC LIGHT IN THE DAYTIME

6. 1. The housewife was asked whether it was necessary to use artificial lighting in the daytime (excluding the twilight period) in mid-summer, that is in June, and in mid-winter—December, and she was asked to say whether this was necessary often, occasionally, or never.

These results are, of course, approximate, and depend to some extent on the housewife's memory. Nevertheless, the results obtained are quite striking in the differences between mid-summer and mid-winter.

The results of this question were analysed into houses and flats, by age of dwelling—pre-war and post-war—and by families of different income groups, namely, under £187 per annum, £187–£260 per annum, and £260–£520 per annum (wage rate of principal wage earner). The purpose of this last analysis was to discover whether or not families in higher income groups lived in houses with better natural lighting.

THE USE OF ARTIFICIAL LIGHTING IN SCULLERY OR WORKING KITCHEN

6. 2. In the scullery or working kitchen 83 per cent of housewives answered that they never needed to use electric lighting in the daytime in summer, 14 per cent said that they had to occasionally, and 3 per cent said that they had to often. In mid-winter the proportions were 41 per cent never, 44 per cent occasionally, and 15 per cent often.

This question was answered by 2150 housewives in relation to mid-summer and 2151 in relation to mid-winter. (Refers to Table 11.)

KITCHEN LIVING ROOM

6. 3. The results in the kitchen living room were almost identical with those of the scullery or working kitchen. In mid-summer the proportion who never found it necessary to use artificial light was 82 per cent, 16 per cent used it occasionally, and 2 per cent used it often, whereas in mid-winter the proportions were 41 per cent, 42 per cent, and 16 per cent respectively. This part of the question was answered by 1890 housewives in relation to mid-summer and 1898 in relation to mid-winter. (Refers to Table 11.)

SITTING ROOM OR PARLOUR

6. 4. The proportions who never found it necessary to use artificial lighting in the sitting room or parlour in mid-summer were 92 per cent, and 8 per cent found it necessary to use artificial lighting occasionally. In mid-winter the proportions were 63 per cent, 33 per cent, and 4 per cent. The number of housewives answering this section of the question were 1765 in relation to mid-summer and 1760 in relation to mid-winter. (Refers to Table 11.)

It should be noted, that this result may have arisen either from the fact that these rooms are less used than the scullery or kitchen living room or from the fact that these rooms have better daylighting.

THE SCULLERIES AND WORKING KITCHENS OF HOUSES AND FLATS COMPARED

6. 5. In the case of the scullery or working kitchen the houses in our sample appeared, generally, to be rather better lit than the flats, as is illustrated by the proportion of housewives who never found it necessary to use artificial light. In mid-summer the proportions were 83 per cent for houses compared with 79 per cent for flats. In mid-winter the proportions were 43 per cent and 31 per cent respectively.

THE KITCHEN LIVING ROOM IN HOUSES AND FLATS COMPARED

6. 6. This analysis shows exactly the same tendency as the analysis of the scullery or working kitchen. In the case of houses 83 per cent found it unnecessary ever to have artificial light in mid-summer compared with 78 per cent in flats. In mid-winter the proportions were 44 per cent and 29 per cent respectively.

Refers to paragraphs 6. 2, 6. 3, and 6. 4

TABLE II

PROPORTIONS OF HOUSEHOLDS FINDING IT NECESSARY TO USE ARTIFICIAL LIGHT IN THE DAYTIME

	MID-SUMMER (JUNE)		MID-WINTER (DECEMBER)	
	No.	%	No.	%
Scullery or Working Kitchen				
Never	1794	83	891	41
Occasionally	313	14	957	44
Often	60	3	312	14
Total answered	2167	100	2160	100
Kitchen Living Room				
Never	1555	82	784	41
Occasionally	296	16	809	43
Often	47	2	297	16
Total answered	1898	100	1890	100
Sitting Room or Parlour				
Never	1620	92	1101	63
Occasionally	136	8	582	33
Often	9	—	77	4
Total answered	1765	100	1760	100

SITTING ROOM OR PARLOUR IN HOUSES AND FLATS COMPARED

6. 7. The analysis of results for sitting room or parlour showed the same tendency as that of the other two rooms. The proportion of housewives living in houses who never used artificial light in mid-summer was 92 per cent compared with 89 per cent in flats, and in mid-winter 65 per cent compared with 47 per cent.

HOUSES AND FLATS COMPARED

6. 8. This analysis shows that houses are better daylighted than flats. It should be borne in mind that the sort of flats most often found in cities and which are available to these income groups are almost always flats of the tenement type, most of them built during the last century and most of them with small windows and thick walls, necessitated by the solid brick or stone structure.

COMPARISON OF THE LIGHTING IN PRE-WAR AND POST-WAR DWELLINGS

6. 9. This analysis shows that the lighting in the post-war dwellings in the sample is much better in all rooms than in pre-war dwellings. The superiority of the post-war dwellings is most marked in the kitchen living room. This is a consequence perhaps of the large amount of buildings undertaken by local authorities in which the kitchen living room is the main room of the house.

The following extract shows the proportion of households who never use artificial light in the three downstairs rooms in mid-summer and in mid-winter:

	MID-SUMMER		MID-WINTER	
	Pre-war	Post-war	Pre-war	Post-war
	% Std. Dev.	% Std. Dev.	% Std. Dev.	% Std. Dev.
Scullery or Working Kitchen	78 ± 1·3	88 ± 1·0	36 ± 1·4	48 ± 1·6
Kitchen Living Room	76 ± 1·4	91 ± 1·0	31 ± 1·4	56 ± 1·8
Sitting Room or Parlour	89 ± ·9	95 ± ·8	57 ± 1·6	70 ± 1·5

COMPARISON OF INCOME GROUPS

6. 10. The households in the sample were divided into three income groups according to the wage of the principal wage earner. They were: Up to £187 per annum, £187–£260 per annum, and £260–£520 per annum.

An analysis of the data into these three groups showed that the rooms of the lower income group need the use of artificial light a little more often in both summer and winter than in the other groups. The results of the other two higher income groups were almost identical.

COMPARISON OF REGIONS

6. 11. The differences in the regions are probably the result of a number of factors, often conflicting factors. Latitude, housing density, and atmospheric pollution may all play a part.

The influence of latitude is shown in the case of Scotland where the proportion of houses where it is never necessary to use artificial light is higher than in all regions, except the Midlands, in summer and lower than all other regions in winter. This result for summer is the more remarkable as housing density is much greater in Scotland than in England since a large proportion of it is of the tenement type.

The influence of less dense housing and of latitude is shown in the high proportion of houses in the South, South-West and Wales which do not need to use artificial light in winter. The absence of smoke in some of these areas may also be a factor.

The influence of dense housing, and possibly atmospheric pollution, is shown by the smaller proportion of houses which do not have to use artificial light in the North. This is true both in summer and winter, although in winter latitude is also important.

House design may also be important, but information was not collected on this point so that its importance could not be assessed.

The following abstract shows the situation:

PROPORTIONS OF FAMILIES WHO NEVER NEED TO USE ARTIFICIAL LIGHT	MID-SUMMER (JUNE)					
	Scotland %	North %	Midlands %	S. and S.W. %	London %	All Regions %
Scullery or Working Kitchen	89	76	91	80	82	83
Kitchen Living Room	84	76	88	79	84	82
Sitting Room or Parlour	91	89	97	89	93	92

PROPORTIONS OF FAMILIES WHO NEVER NEED TO USE ARTIFICIAL LIGHT	MID-WINTER (DECEMBER)					
	Scotland %	North %	Midlands %	S. and S.W. %	London %	All Regions %
Scullery or Working Kitchen	13	32	46	57	41	41
Kitchen Living Room	16	32	46	59	42	41
Sitting Room or Parlour	33	58	68	74	61	63

The standard deviations of the mid-summer percentages are of the order of 2 or less and of the mid-winter percentages are of the order of 3·3 or less.

CONCLUSION

6. 12. The use of artificial light is only important in the winter and most important in the working kitchen or kitchen living room. The proportions having to use artificial light in the sitting room or parlour in mid-winter in the daytime are relatively small. This is possibly due to the fact that the sitting room or parlour is less often used in the daytime than the other rooms, rather than that it is necessarily better lighted.

The separate analyses showed two main points: that houses were rather better lighted than flats, and post-war dwellings were better lighted than pre-war dwellings.

Section VI

7. ASPECT

7. 1. In order to discover the present position about sunlight in the main downstairs rooms, housewives were asked " In what room they got sunshine in winter in the morning and in the afternoon ? " The proportions getting sunlight is determined by the aspect of the house and by the presence or absence of obstruction. Allowing that there are about twelve hours when sunlight is possible in the lighter periods of winter and that these have been included (as sunny days are more likely to have impressed the housewife at this time than her recollection of the shortest day) we should expect that 50 per cent of any type of room would receive direct sunlight in the morning or in the afternoon if these rooms were distributed at random as regards aspect. However, making allowance for the fact that the sun is low during a part of these twelve hours and that in urban areas there are many obstructions, any proportion which was near to this would indicate a southerly aspect predominating for that particular room rather than otherwise. Any proportion, however, very much below the 50 per cent mark would indicate either considerable obstruction or the fact that a large proportion of such rooms were in the north and west in relation to morning sun, or in the north and east in relation to afternoon sun. Latitude is, of course, important here.

MORNING

37 per cent of sculleries or working kitchens had morning sunshine in winter, 41 per cent of kitchen living rooms, and 46 per cent of sitting rooms or parlours. It appears from the comparison of these three rooms that either sitting rooms or parlours are more often in the south than the other rooms, or they are less often obscured.

AFTERNOON

30 per cent of sculleries or working kitchens had afternoon sunshine in winter, 35 per cent of kitchen living rooms, and 44 per cent of sitting rooms or parlours. This analysis shows a similar character to the morning analysis, and again suggests that the sitting room or parlour is either better orientated or less obscured than the other two rooms.

COMPARISON OF HOUSE AND FLAT

7. 2. There are very small differences between the rooms in the houses and flats in this analysis ; flats have sun more often in the kitchen and kitchen living room in the morning than houses and more often in the sitting room or parlour in the afternoon. The proportions having sunlight are given in the abstract below:

	MORNING		AFTERNOON	
	House %	Flat %	House %	Flat %
Scullery or Working Kitchen	36	42	30	27
Kitchen Living Room	42	39	35	29
Sitting Room or Parlour	46	42	44	47

The standard deviation on the house percentages are of the order of 1 and on the flat percentages 3 ; the differences are, therefore, not important.

PRE-WAR AND POST-WAR HOUSES COMPARED

7. 3. This analysis shows the marked advantage of the post-war house over the pre-war house in both morning and afternoon, particularly in the kitchen living room and in the sitting room or parlour. 50 per cent of sitting rooms or parlours in post-war houses had sunlight in the morning and 49 per cent had sunlight in the afternoon compared with 42 per cent and 41 per cent.

	MORNING		AFTERNOON	
	Pre-war %	Post-war %	Pre-war %	Post-war %
Scullery or Working Kitchen	36	38	28	31
Kitchen Living Room	37	47	33	37
Sitting Room or Parlour	42	50	41	49

The standard deviations of these percentages are of the order 1·5.

COMPARISON OF INCOME GROUPS

7. 4. Comparison of income groups shows no very clear differences. The group with the highest proportion having winter sunshine in the scullery is the £260–£520 group, in the kitchen living room it is the under £187 group, and in the sitting room and parlour the £187–£260 group in the morning, and in the afternoon the groups having the highest proportion of sunlight in their sculleries or working kitchens are the under £187 and £187–£260 groups, in the kitchen sitting room the £260–£520 group, and in the sitting room or parlour the £260–£520 group. The differences are all fairly small.

COMPARISON OF REGIONS

7. 5. There were differences between the proportions of each room having sunlight in the morning and the afternoon in the different regions, and the result for Scotland suggests a tendency for sculleries and working kitchens to be orientated towards the south-east as 51 per cent of sculleries or working kitchens have morning sun in winter compared with 27 per cent who have sun in the afternoon. When the influence of latitude is borne in mind and the density of Scottish housing this seems to be a remarkable result.

High figures for all three rooms were obtained in the North and fairly high figures for the kitchen living room or sitting room, and sitting room or parlour in the Midlands in the morning.

In the afternoon fairly low figures were obtained in all sculleries and working kitchens (the North being the highest) and proportions over 40 per cent were obtained in all sitting rooms and parlours in the afternoon.

PROPORTION HAVING DIRECT SUNLIGHT	MORNING				
	Scotland %	North %	Midlands %	S. and S.W. %	London %
Scullery or Working Kitchen	51	40	33	32	37
Kitchen Living Room	33	49	41	38	40
Sitting Room or Parlour	36	51	48	45	43

PROPORTION HAVING DIRECT SUNLIGHT	AFTERNOON				
	Scotland %	North %	Midlands %	S. and S.W. %	London %
Scullery or Working Kitchen	27	37	33	23	26
Kitchen Living Room	28	43	35	32	29
Sitting Room or Parlour	48	47	44	41	45

The standard deviations of these percentages are of the order of 3·5 or less.

HOUSEWIVES' PREFERENCES FOR ASPECT

7. 6. Housewives were asked where they would prefer to have sunlight in the morning or afternoon if they could have it in one room. Only 29 per cent of housewives would like to have sunshine in their scullery or working kitchen in the morning, 45 per cent in the kitchen living room, and 13 per cent in the sitting room or parlour. These two together make 58 per cent of housewives who would prefer to have sunlight in their living room rather than their scullery or working kitchen. 7 per cent of housewives would prefer to have sunshine in their bedroom.

In the afternoon the proportion who would prefer to have sunshine in their scullery or working kitchen is only 5 per cent, 40 per cent would like it in their kitchen living room, and 47 per cent in the sitting room or parlour, a total of 87 per cent who would like it in their sitting room. Only 2 per cent wanted sunlight in their bedrooms in the afternoon.

COMPARISON OF HOUSES AND FLATS

7. 7. There were only small differences between houses and flats, the most important being the greater proportion of flat dwellers, 12 per cent in the morning and 19 per cent in the afternoon, who would prefer to have sunshine in their bedrooms, compared with 6 per cent and 2 per cent of dwellers in houses. This is probably due to the fact that in flats the bedroom has often subsidiary uses.

COMPARISON OF INCOME GROUPS

7. 8. Comparison of the opinions of the different income groups shows a difference in the type of new house expected (or the type of house to which they are accustomed) rather than a difference in preference. The proportion who would like sunshine in their scullery or working kitchen in the morning is approximately the same, whereas the proportion who would like sunshine in the kitchen living room is highest in the lowest income group and goes down as the income rises, the proportion being 52 per cent, 47 per cent, and 39 per cent. This is compensated by the proportions who would prefer sunshine in their sitting room or parlour which have the opposite tendency, 7 per cent, 14 per cent, and 18 per cent. If these two are added together the proportions are very nearly equal, 59 per cent, 61 per cent, and 57 per cent.

In the afternoon the same feature is shown, the proportions for kitchen living room being 54 per cent, 44 per cent, and 23 per cent, and for sitting room or parlour 32 per cent, 42 per cent, and 68 per cent, the totals being 86 per cent, 86 per cent, and 91 per cent.

COMPARISON OF THE REGIONS

7. 9. Comparison of the regions show that the North has a rather smaller proportion who would like sunlight in the scullery or working kitchen in the morning compared with the other regions.

In the afternoon there are no important differences, bearing in mind the interchangeability of the kitchen living room and sitting room or parlour in different house types.

ROOMS IN WHICH SUNSHINE IS DESIRED, ANALYSED IN RELATION TO THE ROOMS IN WHICH SUNSHINE IS OBTAINED AT PRESENT

7. 10. This analysis shows a tendency for housewives to want sunshine in the room in which they already have it in both morning and afternoon. This tendency modifies the general tendency already seen for housewives to prefer to have sunlight in their living room in both morning and afternoon.

This conservatism shows itself in the following way:

In the morning, of those who would prefer sunshine in the scullery or working kitchen 45 per cent already have it there, of those who would prefer it in the kitchen living room 47 per cent already have it there, of those who would prefer sunshine in their sitting room or parlour 60 per cent already have it there, and of those who would prefer it in their bedroom 59 per cent already have it there.

In the afternoon the proportions are, scullery or working kitchen 51 per cent, kitchen living room 39 per cent, sitting room or parlour 45 per cent, bedroom 56 per cent. In all cases these proportions are higher in the case where sunshine is already obtained in the room being discussed than in any other case. (Table 12.)

CONCLUSION

7. 11. In the morning about a third of housewives would prefer sunlight in their scullery or working kitchen and a little less than two-thirds in the sitting room, in the afternoon nearly nine-tenths want sunshine in the sitting room. In many cases housewives want to go on having sunshine in the same rooms as they have it at present.

SECTION VII

8. CONCLUSION

ARTIFICIAL LIGHTING

8. 1. The adequacy of artificial lighting was tested in two main ways:

i. By a detailed lighting analysis of the main downstairs rooms.

and ii. By asking the housewife her views on artificial lighting for her housework.

These inquiries showed:

i. A large proportion of housewives had less light than was necessary for comfort and efficiency at the main working positions measured in foot-candles. This was particularly true for the scullery; lighting measured by watts per square foot was less adequate when electricity was dearer; householders in very many cases had failed to adjust the amount of light used to the size of their rooms; it was also found that the homes of the higher income groups were often better lighted than those of the lower income groups.

ii. Only about one-third of the housewives thought they could see well by artificial light compared with the two-thirds who thought they could see well by daylight.

Refers to paragraphs 7. 10

TABLE 12

ROOMS IN WHICH SUNSHINE IS DESIRED ANALYSED BY ROOMS IN WHICH SUNSHINE IS OBTAINED IN ALL DWELLINGS

SUN OBTAINED IN	SUN DESIRED																							
	IN THE MORNING												IN THE AFTERNOON											
	Scullery or Working Kitchen		Kitchen Living Room		Sitting Room or Parlour		Bed-room		No Answer		All Rooms		Scullery or Working Kitchen		Kitchen Living Room		Sitting Room or Parlour		Bed-room		No Answer		All Rooms	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Scullery or Working Kitchen	310	39	283	35	112	14	62	8	32	4	799	100	65	10	256	40	279	43	13	2	30	5	643	100
Kitchen Living Room	164	21	507	65	45	6	34	4	34	4	784	100	27	4	373	57	217	33	8	1	33	5	658	100
Sitting Room or Parlour	201	25	320	39	192	24	56	7	39	5	808	100	16	2	232	29	497	63	10	1	31	4	786	100
Bedroom	240	26	415	45	128	14	97	11	36	4	916	100	29	4	328	43	329	44	27	4	41	5	754	100
No answer	70	28	·124	49	24	9	10	4	26	10	254	100	20	5	192	44	192	44	9	2	22	5	435	100
SAMPLE	692	29	1082	45	318	13	165	7	118	5	2375	100	128	5	961	40	1121	47	52	2	113	6	2375	100

DAYLIGHTING

8. 2. The adequacy of daylighting was studied in four ways :

i. By finding out with a mirror whether or not there was direct daylight in the places where the main housework was done.

ii. By asking the housewife's opinion as to daylighting in relation to her work.

iii. By finding out whether or not it was necessary to use artificial light in the daytime in winter and summer.

iv. By finding out which rooms had direct sunlight in the morning and in the afternoon.

The main results were as follows :

i. There was direct daylight in most of the main places where the housework was done.

ii. Most housewives (two-thirds or more) thought they could see well when doing their housework by daylight.

iii. The use of artificial light was only important in the winter and then only in the scullery or working kitchen and kitchen living room.

iv. Dwellings appeared not to have been planned in relation to aspect, except in the case of some post-war dwellings and in the case of some of the dwellings in the higher income groups.

STATISTICAL TABLE 1

The Size of Lamps in the Kitchen Living Room

TOTAL WATTS	UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM		ALL INCOMES	
	No.	%	No.	%	No.	%	No.	%
5	1	—	—	—	1	—	2	—
10	—	—	—	—	—	—	—	—
15	3	—	1	—	2	—	6	—
20	—	—	—	—	—	—	—	—
25	20	3	15	2	9	2	44	2
30	—	—	—	—	1	—	1	—
35	1	—	—	—	—	—	1	—
40	130	20	87	12	58	12	275	12
45	1	—	3	—	1	—	5	—
50	4	1	4	1	4	1	12	1
55	—	—	—	—	—	—	—	—
60	292	45	315	44	154	31	761	41
65	—	—	—	—	1	—	1	—
70	2	—	1	—	3	—	6	—
75	59	9	89	12	62	12	210	11
80	4	1	4	1	5	1	13	1
85	1	—	8	1	6	1	15	1
90	—	—	1	—	—	—	1	—
95	—	—	—	—	—	—	—	—
100	111	17	170	24	138	28	419	22
105	—	—	—	—	1	—	1	—
110	—	—	—	—	—	—	—	—
115	2	—	3	—	3	—	8	—
120	2	—	3	—	8	2	13	1
125	—	—	2	—	—	—	2	—
130	—	—	—	—	—	—	—	—
135	—	—	1	—	1	—	2	—
140	2	—	2	—	11	2	15	1
145	—	—	—	—	—	—	—	—
150	3	—	2	—	6	1	11	—

STATISTICAL TABLE 1—*continued*

TOTAL WATTS	UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM		ALL INCOMES	
	No.	%	No.	%	No.	%	No.	%
155	—	—	—	—	1	—	1	—
160	4	1	6	1	6	1	16	1
165	—	—	—	—	—	—	—	—
170	—	—	—	—	—	—	—	—
175	—	—	1	—	1	—	2	—
180	—	—	—	—	7	1	7	—
185	—	—	—	—	—	—	—	—
190	—	—	—	—	—	—	—	—
195	—	—	—	—	—	—	—	—
200	1	—	3	—	4	1	8	—
205	—	—	—	—	—	—	—	—
210	—	—	—	—	—	—	—	—
215	—	—	—	—	—	—	—	—
220	1	—	1	—	2	—	4	—
225	—	—	—	—	1	—	1	—
240	—	—	—	—	1	—	1	—
245	—	—	—	—	1	—	1	—
255	—	—	—	—	1	—	1	—
460	—	—	—	—	1	—	1	—
TOTAL	644 =	100	720 =	100	501 =	100	1867 =	100
No such room / No light / No answer	80	—	168	—	251	—	499	—
SAMPLE	724	—	890	—	752	—	2366	—

[TABLE 2

STATISTICAL TABLE 2

THE SIZE OF ROOMS

Area of Scullery or Working Kitchen in Sq. Ft.

Analysis by House/Flat, Age of Dwelling, Income

SQ. FT.	HOUSE		FLAT		PRE-WAR		POST-WAR		UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM		TOTAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 50	485	26	159	54	407	36	238	24	209	33	258	32	181	25	648	30
51–100	1044	56	95	32	526	46	611	60	332	52	422	53	384	53	1138	53
Over 100	276	15	37	13	166	15	144	14	69	11	99	12	141	19	309	14
Not answered	58	3	4	1	40	3	23	2	25	4	21	3	19	3	65	3
All such rooms	1863	100	295	100	1139	100	1016	100	635	100	800	100	725	100	2160	100

Area of Kitchen Living Room in Sq. Ft.

Analysis by House/Flat, Age of Dwelling, Income

SQ. FT.	HOUSE		FLAT		PRE-WAR		POST-WAR		UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM		TOTAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 100	298	18	48	17	243	22	103	13	128	20	137	19	81	16	346	18
101–150	726	45	138	49	534	49	329	42	312	47	350	48	202	40	864	46
Over 150	573	36	84	30	306	28	351	44	206	31	232	32	221	43	659	35
Not answered	14	1	10	4	15	1	8	1	12	2	8	1	4	1	24	1
All such rooms	1611	100	280	100	1098	100	791	100	658	100	727	100	508	100	1893	100

AREA OF SITTING ROOM OR PARLOUR IN SQ. FT.

Analysis by House/Flat, Age of Dwelling, Income

SQ. FT.	HOUSE		FLAT		PRE-WAR		POST-WAR		UNDER £187 PER ANNUM		£187–£260 PER ANNUM		£260–£520 PER ANNUM		TOTAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 100	179	12	13	6	135	13	57	7	74	18	78	12	40	6	192	11
101–150	547	36	81	37	361	36	267	35	188	47	253	39	187	26	628	36
Over 150	667	43	123	56	421	42	368	49	98	24	260	40	430	61	788	45
Not answered	145	9	3	1	85	9	65	9	45	11	56	9	48	7	149	8
All such rooms	1538	100	220	100	1002	100	757	100	405	100	647	100	705	100	1757	100

There were a small number of cases which were unclassified.

QUESTIONNAIRE

LIGHTING OF DWELLINGS INQUIRY

Serial No............

WARTIME SOCIAL SURVEY
NEW SERIES NO. 24

Interviewer :.............................. Date :...............

Town :......................		Children of School age ?	1
Name of Electricity Co :		Chief Wage-earner : Under £187 p.a.	1
....		£187 to £260 p.a.	2
		£260 to £520 p.a.	3
Dwelling House	1	Occupation	
Flat	2		
Age of Dwelling : Pre-War	1	Cost of Electricity per Unit........	
Post-War	2		
		Where possible give details from Electricity Account :	
Family Size : 1–3	1		
4–7	2	....	
7 and Over	3	....	
		....	

1. Is it necessary to use artificial lighting in the daytime in : (a) Midsummer (June)................ (b) Midwinter (December)...........

	(a)		(b)	
1. In Scullery or Working Kitchen :	Never	1	Never	1
	Occasionally	2	Occasionally	2
	Often	3	Often	3
	No S. or W.K.	4	No S. or W.K.	4
2. In Kitchen Living Room :	Never	1	Never	1
	Occasionally	2	Occasionally	2
	Often	3	Often	3
	No K.L.R.	4	No K.L.R.	4
3. In Sitting Room or Parlour :	Never	1	Never	1
	Occasionally	2	Occasionally	2
	Often	3	Often	3
	No S.R. or P.	4	No S.R. or P.	4

2. Are you able to see well, all right, or badly by artificial light when you are doing the following jobs :

(a) Washing-up	Well	1
	All right	2
	Badly	3
	N.A.	4
(b) Preparing food	Well	1
	All right	2
	Badly	3
	N.A.	4
(c) Cooking	Well	1
	All right	2
	Badly	3
	N.A.	4
(d) Reading or Sewing in Kitchen Living Room	Well	1
	All right	2
	Badly	3
	D.N.A.	4
	N.A.	5
(e) Reading or Sewing in Sitting Room or Parlour	Well	1
	All right	2
	Badly	3
	D.N.A.	4
	N.A.	5

(f) For the Children to see when they are doing homework in the Kitchen Living Room	Well All right Badly D.N.A. N.A.	1 2 3 4 5
(g) For the Children to see when they are doing homework in the Sitting Room	Well All right Badly D.N.A. N.A.	1 2 3 4 5

3. Are you able to see well, all right, or badly by daylight when you are doing the following jobs :

(a) Washing-up	Well All right Badly N.A.	1 2 3 4
(b) Preparing food	Well All right Badly N.A.	1 2 3 4
(c) Cooking	Well All right Badly N.A.	1 2 3 4
(d) Reading or Sewing in Kitchen Living Room	Well All right Badly D.N.A. N.A.	1 2 3 4 5
(e) Reading or Sewing in Sitting Room or Parlour	Well All right Badly D.N.A. N.A.	1 2 3 4 5
(f) For the Children to see when they are doing homework in the Kitchen Living Room	Well All right Badly D.N.A. N.A.	1 2 3 4 5
(g) For the Children to see when they are doing homework in the Sitting Room	Well All right Badly D.N.A. N.A.	1 2 3 4 5

4. Have there been any accidents or mishaps which you think were due to bad lighting in the last month ?
Describe and state whether it happened in daylight or artificial light :

....

....

5. *Observations with Mirror*
Is there visible sky from the following positions :

(a) Centre of bottom of sink	Yes No N.A.	1 2 3
(b) Work-table in Kitchen	Yes No N.A.	1 2 3
(c) Top of Cooker	Yes No N.A.	1 2 3
(d) 3 feet above Floor, 5 feet from Sitting Room or Parlour Fireplace	Yes No N.A.	1 2 3

6. How does the amount of fuel you use for lighting compare with the amount you use for other needs? Would you say that you use most fuel for— (i) Room Heating?		I
(ii) Water Heating?		2
(iii) Cooking?		3
or (iv) Lighting?		4
	N.A.	5
7. The following are a number of fuel-saving hints. Have you tried any of them?		
(i) Do you use fire bricks?	Yes	I
	No	2
	N.A.	3
(ii) Have you "lagged" or insulated (by packing cloth or paper around) your hot-water tank?	Yes	I
	No	2
	N.A.	3
(iii) Do you often have to use your oven for one dish only?	Yes	I
	No	2
	N.A.	3
(iv) Do you use the damper on the kitchen boiler? If so do you find it possible to keep it in most of the time?	Yes	I
	No	2
	D.N.A.	3
	N.A.	4
8. Have you or has anybody in your family worked out your fuel target?	Yes	I
	No	2
	N.A.	3
IF YES		
9. Do *you* know how many fuel units you have got?	Yes	I
	No	2
	N.A.	3

TO ALL

10. What kind of things will you be able to do to keep your fuel consumption down?

....

....

....

11. Have you stored any fuel for the winter? Say what.

....

12. Where do you get sunshine in your present house in winter?

ROOM	IN THE MORNING	IN THE AFTERNOON
1. Scullery or Working Kitchen	I	I
2. Kitchen Living Room	2	2
3. Sitting Room or Parlour	3	3
4. Bedroom	4	4

13. (a) If you had a new house in which room would you choose to have the sun *in the morning* if it was possible to have it in one room only?

ROOM	MORNING
1. Scullery or Working Kitchen	I
2. Kitchen Living Room	2
3. Sitting Room or Parlour	3
4. Bedroom	4

(b) In the afternoon

ROOM	AFTERNOON
1. Scullery or Working Kitchen	I
2. Kitchen Living Room	2
3. Sitting Room or Parlour	3
4. Bedroom	4

14				DIMENSIONS		OFFICE USE		POSITION OF FITTINGS		FITTINGS		WALLS	CEILING	OFFICE USE	METER READINGS BY ELECTRIC LIGHT								
ROOM	SIZE OF LAMPS		TOTAL WATTS	Length	Breadth	Areas Sq. Ft.	Watts per Sq. Ft.	Ceiling 1 Bracket 2 Movable 3		Direct a. 1 Direct b. 2 S. Direct 3 General 4 S. Indirect 5 Indirect 6		Light 1 Dark 2	Light 1 V. Light 2	Factor	A. Unshadowed B. As Used Scullery or Working Kitchen						Living Room or Parlour 5 ft from Fire	PRE-WAR LAMPS	OFFICE USE
															Sink		Cooker		Table				
								Code Below		Code Below		Code	Code		A	B	A	B	A	B	A		
1. Scullery or Working Kitchen	1st	2nd						1st	2nd	1st	2nd												
2. Kitchen Living Room																							
3. Sitting Room or Parlour																							

15	HOURS LIGHT USED		TOTAL	TIME OF		OFFICE USE	OFFICE USE	OFFICE USE
ROOM	Last Evening	This Morning		RISING	BED			
1. Scullery or Working Kitchen								
2. Kitchen Living Room								
3. Sitting Room or Parlour								

APPENDIX VII. ESTIMATE OF INCREASED COSTS RESULTING FROM THE RECOMMENDATIONS FOR IMPROVED STANDARDS OF ARTIFICIAL LIGHTING IN DWELLINGS

RUNNING COSTS

WORKING KITCHENS AND SCULLERIES

From the figures given in the Lighting of Dwellings Inquiry it may be assumed that the recommended standards would involve an increase in the case of electric lighting from something like 40 watts to 100 watts in the 80 sq. ft. room and from 40 watts to 115 watts in the larger rooms. Information supplied by the South Metropolitan Gas Company suggests that past practice for gas might be taken as being one *B.S.* 3 mantle for small rooms and one *B.S.* 4 mantle for the larger rooms. Tables A. VII/1 and A. VII/2 show the annual running cost of the old and new standards and the difference between these for varying rates of charge. The figures are based on an annual usage of 600 hours with the full lighting in use.

It may be noticed that the figures in Tables A. VII/1 and A. VII/2 suggest that the increased running costs for gas are apparently considerably lower than for electricity. This is due to the assumptions made as to present standards of lighting. For electricity these are based on the Lighting of Dwellings Inquiry, while for gas they are based on information from Gas Companies in whose area the average standard was rather higher than that found to be general with electricity. No doubt this may be to some extent due to the sizes of lamps and mantles commonly available.

The Lighting of Dwellings Inquiry (A. VI) clearly shows the effect of cost on the amount of light used by the lower income groups. Tables 1 and 2 show how considerable would be the effect of a low unit rate such as is usually obtainable in the two-part tariff system.

LIVING ROOMS

The Lighting of Dwellings Inquiry shows the following figures for electric lighting.

TABLE A. VII/3. PERCENTAGE OF LIVING ROOMS HAVING MORE THAN ONE LIGHT FITTING (INCLUDING MOVABLE LIGHTS)

INCOME UNDER £187 P.A.	£187–£260	£260–£520
2	7·7	23·2

The Inquiry also shows that at present the total wattage used in living rooms is as follows:

TABLE A. VII/4. PERCENTAGE OF LIVING ROOMS USING VARIOUS WATTAGE

TOTAL WATTS USED	INCOME UNDER £187 P.A.	£187–£260	£260–£520	ALL INCOMES
Up to 25	10	4	2	4
26–50	23	12	8	13
51–75	55	54	32	45
76 and over	13	30	58	38

TABLE A. VII/1. ANNUAL RUNNING COST OF ELECTRICITY IN WORKING KITCHEN OR SCULLERY

SIZE OF WORKING KITCHEN OR SCULLERY	ELECTRICITY COST PER UNIT														
	½d.			1d.			2d.			4d.			8d.		
	ANNUAL RUNNING COST			ANNUAL RUNNING COST			ANNUAL RUNNING COST			ANNUAL RUNNING COST			ANNUAL RUNNING COST		
	Old	New	Difference	Old	New	Difference	Old	New	Difference	Old	New	Difference	Old	New	Difference
Up to 80 sq. ft.	1/-	2/6	1/6	2/-	5/-	3/-	4/-	10/-	6/-	8/-	20/-	12/-	16/-	40/-	24/-
80–120 sq. ft.	1/-	2/10½	1/10½	2/-	5/9	3/9	4/-	11/6	7/6	8/-	23/-	15/-	16/-	46/-	30/-

TABLE A. VII/2. ANNUAL RUNNING COST OF GAS IN WORKING KITCHEN OR SCULLERY

SIZE OF WORKING KITCHEN OR SCULLERY	GAS PRICE PER THERM								
	4d.			8d.			12d.		
	ANNUAL RUNNING COST			ANNUAL RUNNING COST			ANNUAL RUNNING COST		
	Old	New	Difference	Old	New	Difference	Old	New	Difference
Up to 80 sq. ft.	3/2	6/4	3/2	6/4	12/8	6/4	9/6	19/-	9/6
80–120 sq. ft.	4/4	6/10	2/6	8/8	13/8	5/-	13/-	20/6	7/6

Note: The actual difference between new and old standards would usually be somewhat less as it would not be necessary to keep two light sources burning for the full 600 hours. On the other hand, there would be the additional cost of periodically renewing one additional lamp or mantle.

Figures in the columns for old and new charges are exclusive of the standing charge, if any, and of any charge for the cost of installation. Therefore the column headed " Difference " does not indicate the percentage increase on the total annual cost of gas or electricity.

For the purpose of calculating increased costs due to the recommended standards the present wattage for living rooms has been taken as 60 watts.

The increase in wattage in raising the present standards to the recommended standards in these examples would be of the order indicated in Table A. VII/5.

TABLE A. VII/5

INCREASE IN WATTAGE ABOVE CURRENT PRACTICE

ROOM SIZE	FITTING		
	Type A	Type B	Type C
120 sq. ft.	40	40	140
150 sq. ft.	90	90	140
200 sq. ft.	90	140	240

Table A. VII/6 shows the annual running cost in these three examples in terms of old and new costs and difference for varying rates of charge. The figures are based on an annual usage of 1000 hours.

This table again illustrates the importance of the tariff charge. At the same time it also emphasizes the cost to the consumer if certain types of fittings are used, the additional running cost being very considerable if Type C fittings are used. The Lighting of Dwellings Inquiry showed that only about 30 per cent of the people in the lower income groups used indirect or semi-direct fittings in living rooms.

These running costs are for the fixed fitting only. Our recommendations include for plug points in addition, and it is to be hoped that these will be used for supplementary lighting.

If it is assumed that there is a 500 hour usage of a 60 watt lamp for local lighting the running costs would be as shown in Table A. VII/7.

TABLE A. VII/7. RUNNING COSTS FOR SUPPLEMENTARY LIGHTING (ELECTRICITY)

ELECTRICITY COST PER UNIT				
½*d.*	1*d.*	2*d.*	4*d.*	8*d.*
1/3	2/6	5/-	10/-	20/-

Note: To this there would be added the additional cost of periodically renewing lamps.

In the case of gas lighting raising the present standard, taken as one *B.S.* 4 in all cases, would entail increases in B.Th.U. rate as given in Table A. VII/8.

TABLE A. VII/6. ANNUAL RUNNING COST FOR MAIN FITTING IN LIVING ROOMS (ELECTRICITY)

SIZE OF ROOM	TYPE OF FITTING	ELECTRICITY COST PER UNIT														
		½d.			1d.			2d.			4d.			8d.		
		ANNUAL RUNNING COST			ANNUAL RUNNING COST			ANNUAL RUNNING COST			ANNUAL RUNNING COST			ANNUAL RUNNING COST		
		Old	New	Difference	Old	New	Difference	Old	New	Difference	Old	New	Difference	Old	New	Difference
120 sq. ft.	A B C	2/6	4/2 4/2 8/4	1/8 1/8 5/10	5/-	8/4 8/4 16/8	3/4 3/4 11/8	10/-	16/8 16/8 33/4	6/8 6/8 23/4	20/-	33/4 33/4 66/8	13/4 13/4 46/8	40/-	66/8 66/8 133/4	26/8 26/8 93/4
150 sq. ft.	A B C	2/6	6/3 6/3 8/4	3/9 3/9 5/10	5/-	12/6 12/6 16/8	7/6 7/6 11/8	10/-	25/- 25/- 33/4	15/- 15/- 23/4	20/-	50/- 50/- 66/8	30/- 30/- 46/8	40/-	100/- 100/- 133/4	60/- 60/- 93/4
200 sq. ft.	A B C	2/6	6/3 8/4 12/6	3/9 5/10 10/-	5/-	12/6 16/8 25/-	7/6 11/8 20/-	10/-	25/- 33/4 50/-	15/- 23/4 40/-	20/-	50/- 66/8 100/-	30/- 46/8 80/-	40/-	100/- 133/4 200/-	60/- 93/4 160/-

Note: There would be the additional cost of periodically renewing lamps of larger size than in the pre-war standard. Figures in columns for old and new charges are exclusive of the cost for a standing charge, if any, and of any charge for the cost of installation. Therefore the columns headed " Difference " do not indicate the percentage increase on the total annual cost of electricity.

TABLE A. VII/8. INCREASE IN B.TH.U. RATE ABOVE CURRENT PRACTICE

ROOM SIZE	TYPE OF FITTING	
	A	B
120 sq. ft.	200 B.Th.U./hr.	900 B.Th.U./hr.
150 „	900 „ „	1,300 „ „
200 „	1,300 „ „	3,100 „ „

Table A. VII/9 shows the annual running cost in these examples in terms of old and new costs for varying rates of charge. The figures are based on an annual usage of 1000 hours.

TABLE A. VII/9. ANNUAL RUNNING COST OF MAIN FITTING IN LIVING ROOMS (GAS)

ROOM SIZE	TYPE OF FITTING	GAS COST PER THERM								
		4*d.*			8*d.*			12*d.*		
		Old	New	Difference	Old	New	Difference	Old	New	Difference
120 sq. ft.	A	7/8	8/4	8*d.*	15/4	16/8	1/4	23/-	25/-	2/-
	B		10/8	3/-		21/4	6/		32/-	9/-
150 sq. ft.	A	7/8	10/8	3/-	15/4	21/4	6/-	23/-	32/-	9/-
	B		12/-	4/4		24/-	8/8		36/-	13/-
200 sq. ft.	A	7/8	12/-	4/4	15/4	24/-	8/8	23/-	36/-	13/-
	B		18/-	10/4		36/-	20/8		54/-	31/-

Note: There would be the additional cost of periodically renewing mantles of larger size than in the pre-war standard. Figures in columns for old and new charge are exclusive of any cost for a standing charge. Therefore the columns headed " Difference " do not indicate the percentage increase on the total annual cost of gas.

These running costs are for the fixed fitting only. If it is assumed that there will be a 500-hour usage of a *B.S.* 4 mantle for local lighting the running costs would be as shown in Table A. VII/10.

TABLE A. VII/10. RUNNING COST FOR SUPPLEMENTARY LIGHTING (GAS)

GAS COST PER THERM		
4*d.*	8*d.*	12*d.*
3/10	7/8	11/6

BEDROOMS

The running costs are unlikely to be appreciably affected by our recommendations. The slight additional cost due to the comparatively small usage of a larger lamp for the general light would be, at least to some extent, offset by the possibility of using a small lamp for the bed light which may be in use for considerable periods during illness and for reading in bed.

CAPITAL COSTS OF INSTALLATIONS TO MEET THE ABOVE RECOMMENDATIONS

The main increase in capital cost will be due to increased wiring or piping required for additional outlets. We have obtained estimates of costs from the Electrical Installations Committee and the Gas Installations Committee. These are in terms of 1938 prices and for quantities of 100 similar houses at a time. Tables A. VII/11 and A. VII/12 summarize the information.

THE EFFECT OF INTERNAL DECORATIONS ON ARTIFICIAL LIGHTING

The effect of internal decoration on the performance of a given artificial lighting system may be most marked, not only as regards the general appearance of the rooms but also as regards the actual illumination produced.

In an indirect lighting system any reduction in the reflection factor of the ceiling causes a proportional reduction in the illumination. For a direct lighting system the effect is not so marked but is still not negligible. Table A. VII/13 illustrates the order of these effects and shows the relative values of illumination produced by three typical lighting systems with different conditions of the decoration, the illumination with the lightest being taken as 100 per cent in each case.

It is therefore strongly recommended that decorations to walls and ceilings should be of high reflecting values both to improve the cheerful appearance and to give higher illumination values. In the case of floors, while the effect on illumination values may be small, the use of a light tone is most valuable in enhancing the cheerful appearance of a room; consequently we recommend the use of light-coloured floors wherever possible.

[TABLE

TABLE A. VII/11. ESTIMATED COMPARATIVE COSTS OF PRE-WAR AND RECOMMENDED POST-WAR ELECTRICAL INSTALLATIONS

M.O.H. Post-War Rural 3 bedroom, parlour house. Outbuildings not included. (Approximate area 950 square feet.) Screwed Steel Conduit, including all necessary switches, socket-outlets, and other accessories, but excluding fittings. Estimates based on 100 installations; net cost of labour and materials without allowance for overhead or profit: 1938 prices. Labour based on London rate without fares or country allowance.

INSTALLATIONS	COST OF INSTALLATION PER HOUSE					
	CONSUMER'S SUPPLY CONTROL	LIGHTING	COOKER	SOCKET-OUTLET "RING" CIRCUIT		COMPLETE INSTALLATION PER HOUSE
				Under Floor [1]	In Wall duct [2 3]	
1. Typical pre-war installations	—	(10 points)	—	(3 outlets)	—	—
(a) (b)	£1 4 10 —	£6 18 7 —	— —	£2 15 8 —	— —	£11 0 0 —
2. Post-war installation to provide all lighting requirements suggested by Lighting Committee	—	(12 points)	—	(9 outlets)	(9 points)	—
(a) (b)	£1 12 4	£7 9 7	£1 5 3	say £5 4 0 —	— say £5 13 0	say £16 0 0
3. Post-war installation to provide all lighting and power requirements (generally in accordance with the proposals of M.O.W. Electrical Installations Committee)	—	(13 points)	—	(18 outlets)	(18 outlets)	—
(a) (b)	£1 12 4	£7 14 10	£1 5 3	£9 17 10 —	— £11 4 7	£20 10 0 £21 17 0

[1] Assumes timber-joist OR concrete floors in which all notching, formation of chases and making good is carried out by the building contractor.
[2] Suggested preformed wall duct 9 in. above floor level throughout house.
[3] The cost of maintenance of the post-war installations would be approximately 1*s*. 6*d*. per house per year.

TABLE A. VII/12. ESTIMATED COMPARATIVE COSTS OF PRE-WAR AND RECOMMENDED POST-WAR GAS INSTALLATIONS

Estimates based on 100 installations. 1938 prices. Prices are for prime costs of labour and material without allowance for establishment charges and profit.

	LIGHTING POINTS	FIRE POINTS	PLUG POINTS	COOKER COPPER WATER HEATER	TOTAL NO. OF POINTS	AVERAGE PRICE PER POINT	TOTAL
1. Typical pre-war	11	2	2	3	18	8/4	£7 4 0
2. Post-war (Cavity walls, joists and boarded floor, span-roof. Pipe runs planned to avoid chasing of walls, or notching of joists except near a bearing wall.)	12	4	9	3	28	8/6	£11 18 0
3. Post-war (Brick or concrete walls with solid floor and flat roof. Assumed that provision has been made for ducts or channels to be formed in floors and roof or that space between concrete beams will permit pipes being laid therein. Minimum size of pipes embedded in floors is ½-in. bore.)	12	4	9	3	28	9/6	£13 6 0

Note: Additional cost per point to fit plug in terminal with fan key cock 5*s.* 6*d.* Meter enclosure of fire-resisting material at front of house. All service and internal installation pipes and pipe fittings to be of materials approved by the Institution of Gas Engineers, installed in accordance with the Rules of Good Practice formulated by The Gas Installations Committee convened by the said Institution.

TABLE A. VII/13. EFFECT OF DECORATION ON ILLUMINATION

SYSTEM OF LIGHTING	LIGHT WALLS AND CEILING	DARK WALLS LIGHT CEILING	DARK WALLS AND CEILING
Direct	100	85	75
General	100	80	65
Indirect	100	75	30

APPENDIX VIII
A METHOD OF MEASURING INSOLATION

BY P. V. BURNETT, F.R.I.B.A.

The problem of obtaining a fair picture of sunlight at all seasons of the year has always been a difficult one, and no satisfactory method has yet been evolved of simple comparison of the effect of different aspects without reference to separate tables or diagrams for each season. It is suggested that this difficulty could be overcome by adding the hours of possible sunlight for the four seasons together, the total being an all-the-year-round figure for the particular aspect under consideration which could be termed "sun-units." As an example, for south aspect for unobstructed conditions the possible sun-unit value would be as follows (to the nearest quarter of an hour):

Midsummer	9¼ hours
Midwinter	7½ "
Vernal equinox	12 "
Autumnal equinox	12 "
Total	40¾ sun-units (possible)

Possible sun-unit values for all aspects in this manner would enable different aspects to be compared, taking into account all seasons, and such values are attached Table A. VIII.

But it is doubtful whether possible sunlight is the best basis for comparison, because it gives equal relative values to sunlight in summer and winter, whilst in fact the probability of sunlight in winter is far less than in summer. Therefore it is suggested that probable sunlight is a better basis, and the ratios of probability to possibility for the south of England, averaged over 35 years, from the Book of Normals of the Meteorological Office (areas 3, 4 and 5 averaged) are:

Midsummer	0·41
Midwinter	0·17
Vernal equinox	0·32
Autumnal equinox	0·40

By applying these ratios to the possible sun-units, the following is an example, for the south aspect referred to above:

Midsummer	3·79
Midwinter	1·27
Vernal equinox	3·84
Autumnal equinox	4·80
Total	13·70 sun-units (probable)

Probable sun-units of this character provide a more likely picture of the sunlight that will actually be received, and the values for all aspects are attached Table A. VIII.

But although such values do provide a fair representation of all probable sunlight, not all probable sunlight is useful, and it is suggested that sunlight before 7 a.m.

(G.M.T.) is of very little value within buildings, and if included in measurements of insolation can lead to misleading results. It is therefore suggested that all sunlight before 7 a.m. should be excluded for this purpose, and the corrected values are attached Table A. VIII.

The effects of obstructions are even more important for sunlight than for daylight, because either sunlight penetrates or it does not, there is no intervening stage; whilst with daylight there is infinite variation between daylight and darkness. The effect of these obstructions is easily assessable by a variety of methods, and can be tabulated, and attached is a master-graph showing the values of probable sun-units for all aspects and all obstructions up to 50°, excluding sunlight before 7 a.m., which enables any sort of comparison to be made quickly.

The use of these sun-unit values can be explained in a few examples. Houses are normally of three types, detached, semi-detached, or terraced, having windows on four, three, or two sides respectively. Semi-detached houses usually have an obstruction opposite the end wall, so that detached and terraced houses only will be considered. For this purpose, if we confine consideration to divisions of $22\frac{1}{2}°$ of bearing, detached houses can have only four orientations, and these, together with their sun-unit values, as shown below:

DETACHED HOUSES. WINDOWS ON FOUR SIDES. UNOBSTRUCTED

ASPECTS					SUN-UNIT VALUES				TOTALS
1.	N.	S.	E.	W.	1·54	12·98	6·29	8·34	29·15
2.	NNE.	SSW.	ESE.	WNW.	1·97	12·63	7·75	6·47	28·82
3.	NE.	SW.	SE.	NW.	3·21	11·63	9·58	5·26	29·68
4.	ENE.	WSW.	SSE.	NNW.	4·28	9·80	11·19	3·41	28·63

It will be obvious that as the sun traverses a complete circle daily, all probable sun will fall upon one face or another of a detached house, and that the totals for all four faces must be nearly the same. But in case four it will be seen that there is the least variation between the four aspects (3·41–11·19) so that this orientation is the best for the unobstructed condition examined.

A similar examination of the orientation of terraced houses follows:

TERRACED HOUSES. WINDOW ON TWO SIDES. UNOBSTRUCTED

ASPECTS			SUN-UNIT VALUES		TOTALS
1.	N.	S.	1·54	12·98	14·52
2.	NNE.	SSW.	1·97	12·63	14·60
3.	NE.	SW.	3·21	11·63	14·84
4.	ENE.	WSW.	4·82	9·80	14·62
5.	E.	W.	6·29	8·34	14·63
6.	ESE.	WNW.	7·75	6·47	14·22
7.	SE.	NW.	9·58	5·26	14·84
8.	SSE.	NNW.	11·19	3·41	14·60

From this table it will be seen that ESE.–WNW. gives the least variation, whilst E.–W. is also good.

By means of the master-graph attached (Fig. 67) it should be simple for a designer, having taken the altitude of obstruction for all main directions on the site, to compare all possible orientations and select the best, having taken regard of all circumstances that can be foreseen or exist. The sharp fall in values of sun-units for aspects near south for obstructions between 30° and 40° altitude is clearly shown in the graph. Obviously sites with obstructions higher than about 25° are unsuitable for housing.

TABLE A. VIII. SUN UNIT VALUES IN S.E. ENGLAND

	POSSIBLE VALUES	PROBABLE VALUES	PROBABLE VALUES EXCLUDING SUNLIGHT BEFORE 7 A.M. (G.M.T.)
N.	7	2·87	1·54
NNE.	10·25	4·03	1·97
NE.	14	5·26	3·21
ENE.	18·25	6·87	4·82
E.	24	8·34	6·29
ESE.	28·75	9·80	7·75
SE.	34·75	11·83	9·58
SSE.	37·75	12·64	11·19
S.	40·75	13·70	12·98
SSW.	37·75	12·64	12·63
SW.	34·75	11·83	11·63
WSW.	28·75	9·80	9·80
W.	24	8·34	8·34
WNW.	18·25	6·87	6·47
NW.	14	5·26	5·26
NNW.	10·25	4·03	3·41

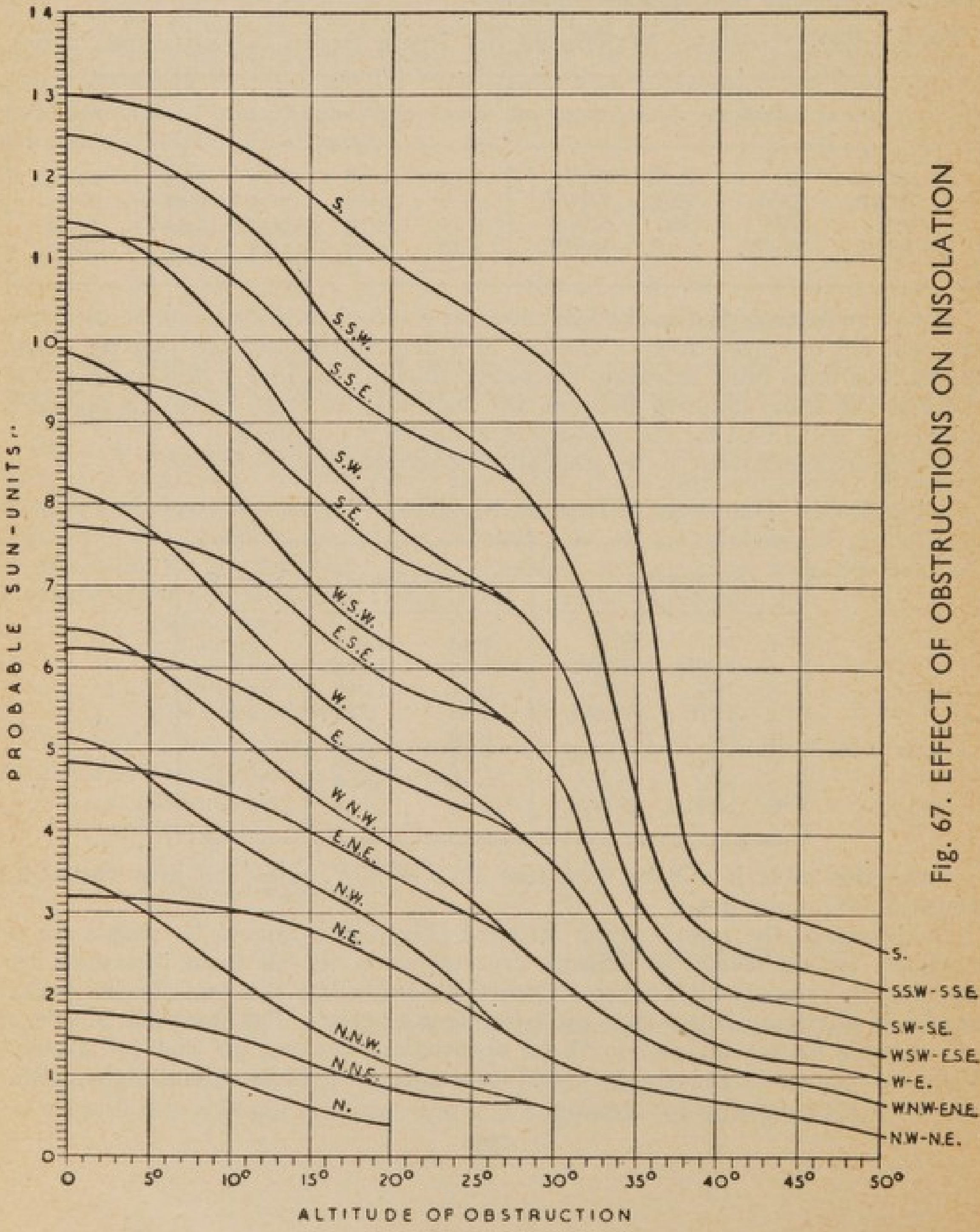


Fig. 67. EFFECT OF OBSTRUCTIONS ON INSOLATION

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