POST-WAR BUILDING STUDIES

NO. 30

THE LIGHTING OF OFFICE BUILDINGS

BY

THE LIGHTING COMMITTEE

OF THE BUILDING RESEARCH BOARD

OF THE DEPARTMENT OF

SCIENTIFIC & INDUSTRIAL RESEARCH

LONDON: 1952

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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: 1952

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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, were appointed by you in February 1942 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).

In 1944, we presented our First Report on *The Lighting of Buildings*, which was published as No. 12 in the series of *Post-War Building Studies*. This Report included a consideration of the general principles of lighting and a detailed study of the lighting of dwellings and schools.

We did not carry our work further at that time, but in December 1946 you asked us to take up our work again and to prepare a report on the Lighting of Office Buildings.

In July 1948 we suffered a great loss by the death of Sir Clifford Paterson who had been our chairman since the Committee was first set up in 1942. It is a great sorrow to us all that he has not been able to see the completion of our Second Report, in which he had taken great personal interest. We wish to record the debt which we owe to him for his help and guidance in our work.

We also wish to record our sorrow at the loss of Mr. Dow, who died in August 1948. He was a member of the Committee from its inception until February 1948, when he had to retire through ill-health.

The Committee have held eleven meetings and in addition two sub-committees which were appointed to study natural lighting and artificial lighting respectively, have met on numerous occasions, sometimes separately and sometimes jointly.

SOURCES OF INFORMATION

In accordance with our Terms of Reference we have reviewed existing published information on the lighting of offices and have taken evidence from a number of experts and bodies specially concerned.

The following associations who submitted evidence for the earlier Report and who included information on office lighting were invited to add to their previous comments, but all agreed that they had nothing to add to their original evidence:

British Electrical Development Association.
Electrical Contractors Association, Inc.
Electric Lamp Manufacturers' Association.
Electric Light Fittings Association.
The Illuminating Engineering Society.

also

Mr. P. V. Burnett, F.R.I.B.A., who while a member of the Committee gave evidence in his personal capacity.

The views of staff on office lighting, and opinions on the design of offices and the effect of lighting on office rental values, were obtained from the following associations and individuals:

Opinions of Office Staff

Association of Engineering and Shipbuilding Draughtsmen, represented by
Mr. John Holland (Asst. Gen. Secretary).
Mr. Gordon Davidson.
Mrs. C. Bourne.

Civil Service Clerical Association, represented by
Mr. W. J. Ellerby (Asst. Gen. Secretary).

National Union of Bank Employees, represented by
Mr. T. G. Edwards (General Secretary).

Design of Offices

Mr. C. Lovett Gill, F.R.I.B.A.
Mr. L. Sylvester Sullivan, F.R.I.B.A.
(Nominated by the Royal Institute of British Architects.)

The Economic Aspect of Office Lighting

The Director of Lands and Accommodation, Ministry of Works.
Mr. G. Leslie Head, M.Inst.R.A., A.I.Struct.E., M.R.San.I.
Mr. E. E. Saunders, F.R.I.C.S., F.A.I.

Their evidence was received verbally and has been summarized as Appendix II to this Report.

The inquiries carried out for our earlier Report to obtain information about existing lighting practice in dwellings had proved very useful. We therefore asked the Social Survey Division of the Central Office of Information to carry out a similar survey of offices throughout Britain in order to obtain evidence about the state of office lighting at the present time. We consider this a valuable piece of work and we acknowledge our indebtedness to the Director of Social Survey and his staff for their work. The results are given in Appendix I.

Through the courtesy of Mr. R. J. Hitchcock and Mr. E. M. Waring, of the London Passenger Transport Board ; Mr. P. R. L. Keelan, of Messrs. John Lewis and Co. ; the late Dr. L. G. Comrie, M.A., Ph.D., F.R.S., of the Scientific Computing Service Ltd., and Mr. Gordon G. Reed, of Barclays Bank Ltd., we were able to visit various office buildings in London which have interesting points about their lighting. Additional information was supplied by the Chief Architect to the London County Council.

We record our thanks to these individuals, associations and authorities for their help, so willingly given. We also wish to thank the General Electric Company Ltd. and the Chief Engineer, Ministry of Works, for the generous loan of a large number of illumination meters which enabled important parts of the Survey to be done, and to the City of London Real Property Co. Ltd. for the loan of drawings of office buildings in the City of London.

Finally, we wish to acknowledge our thanks, for their assistance, to Dr. J. W. T. Walsh of the National Physical Laboratory and to the members of the staff of the Building Research Station, in particular to Mr. W. A. Allen and Dr. R. G. Hopkinson and to Mr. J. A. Godfrey for his valuable work as Secretary to the Committee.

P. V. Burnett, *Chairman*
R. O. Ackerley
H. Austen Hall
H. Hartridge
H. A. Hepburn
R. S. Morton
A. Scott
N. Sizer
F. C. Smith
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H. C. Weston
J. A. Godfrey, *Secretary*

5th September, 1950.

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ACKNOWLEDGEMENTS

The photographs of 59/60 Mark Row, London (Plate I) and of offices at Wallsend (Plate II) are reproduced by permission of the Architectural Press Ltd.; that of the Prudential Building, Los Angeles, by permission of Julius Shulman; and the photograph of the offices of W. D. and H. O. Wills Ltd., by permission of the National Buildings Record.

THE LIGHTING OF OFFICE BUILDINGS

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

SCOPE OF THE REPORT

1. The Report opens with a brief historical note in Part I on the design of office buildings and the state of office lighting at the present time.

Part II of the Report deals with natural lighting. It first discusses general opinions about the use of daylight. The modern technique of urban development by which good daylighting can be ensured is next considered, and following a brief classification of office accommodation and the main types of office work, recommendations are made for standards of lighting. The possibility of extending the useful zone of daylight by supplementary artificial lighting is also discussed.

Part III deals with artificial lighting. The visual difficulties of office work are examined, recommendations for standards are made, and the characteristics of light fittings reviewed. Decorations and surface finishes play an important part in producing good conditions for vision and these are also discussed. Some of the main requirements for lighting specific rooms such as private offices, general clerical offices, typing rooms, etc., are next considered, and finally, brief reference is made to methods of installing electric wiring and gas supply pipes.

Part IV reviews various expedients for improving the illumination of existing buildings, and Part V is a discussion on the desirability of legislative control.

SUMMARY OF CONCLUSIONS

NATURAL LIGHTING

2. The evidence from the staff associations showed that, in general, staff wanted rooms with adequate natural light and this was supported by the expert witnesses, who regarded good daylight as an important factor in assessing the value of office accommodation. Modern methods of urban development are making it possible to have good daylighting without prejudice to normal densities of development; and despite administrative difficulties in changing from the traditional to the new technique, steady progress is now evident. Such development makes possible a reasonable depth of well-daylighted space inside buildings, but for design purposes it is necessary to be able to specify it more exactly.

We recommend, therefore, that in the parts of buildings intended for office use, a sky factor[1] *of 1 per cent. should be provided at a point not less than 12 ft. inwards*

[1] The daylight obtainable at a point in a room is usually expressed as a ratio of that obtainable outdoors. Until the 1939 meeting of the International Commission on Illumination only one form of this ratio had been defined, i.e. *the daylight factor*. This ratio expresses the horizontal illumination at a point indoors as a percentage of that received outside from a completely unobstructed hemisphere of sky, direct sunlight being excluded. It includes the effect of light reflected from walls, ceilings and other surfaces and losses due to transmission through window glass and any overlying dirt. It is conveniently measurable by instruments but difficult to compute by geometric methods.

In 1939 another form of the ratio was defined, the *sky factor*. This is a purely geometric quantity and depends only on the angular dimensions of the bounding edges of the patches of sky as visible from the reference point and their orientation relative to the working plane. It is similar in effect to the daylight factor but is based on the assumption of a sky of uniform brightness, no contributions due to reflected light and no losses through the window glass. The particular merit of the sky factor is that it can be easily computed from drawings by one of a number of accepted methods.

Since the sky factor was defined some of the methods of computation, *e.g.* the Building Research Station "daylight factor" protractors and the graded "daylight factor" tables, *from the outer face of the wall.* This standard should not generally require windows of unreasonable size, but it suggests the use of the traditional arrangement of graded storey heights in the lower parts of buildings. We describe how this standard may be conveniently determined.

Drawing offices require special treatment and are frequently best served by overhead lighting. *We recommend that they should generally have a minimum sky factor of 5 per cent.*

Effective measures should be taken to reduce sky glare, and we describe the chief points about window design which help to minimise visual discomfort and disability.

We have considered sunlight. Some of the expert witnesses did not think the admission of sunlight important but the survey showed that office staffs valued it. We think architects should take sunlight into account when planning office buildings, but we also consider it to be important that blinds or other means of excluding unwanted sunlight should be provided.

ARTIFICIAL LIGHTING TO SUPPLEMENT DAYLIGHT

In America some buildings have been planned without regard to daylight, reliance being placed on artificial light as the main illumination. It is not known whether buildings so designed are satisfactory, but the very deep office spaces made practicable by this means would affect fundamentally the economy of office blocks. Because daylight is greatly valued in this country it is not thought this treatment would find acceptance for new buildings, although it is often necessary for older structures. Artificial light affords a more effective method of improving inadequately daylighted offices than many of the minor expedients, such as external reflectors, and even in new buildings it can make acceptable for daytime use the areas which cannot be properly daylighted. The factors necessary for success are described in the Report. In our opinion supplementary artificial light should add at least 10 ft. to the depth of office which appears to be well daylighted.

ARTIFICIAL LIGHTING

With artificial lighting it is necessary and quite feasible to adjust the lighting to the type of work. We have, therefore, provided detailed comments on the nature of the visual demands involved. While good lighting can make office work easier there are some kinds of work which are needlessly difficult but can be improved by office managements. We make detailed suggestions for such improvements.

Our analysis of office work enables us to make firm recommendations concerning the values of illumination to be provided :

For book-keeping, typing, computing machine work, filing and general office work, we recommend values of the order of 20 *lm./sq. ft.*[1] *Where work is intermittent this value can be reduced, but not below one-half.*

For drawing-office work, which is very exacting, we recommend 30-50 *lm./sq. ft., depending on the nature of the work.*

For private offices we recommend 15 *lm./sq. ft. and for inquiry and reception rooms, crush and entrance halls,* 6 *lm./sq. ft.*

These values permit high, but not maximum, visual efficiency. They are based on known facts about visual performance and, so long as office work remains

have been extended to include the effect of the varying transmission of window glass with the angle of the incident light. This modified form of sky factor is the one referred to in the Report.

Measurements of sky factor and daylight factor are usually made on a horizontal plane assumed to be 2′ 9″ above floor level.

[1] lm./sq. ft. = lumens per square foot.

One lumen is the amount of light flux emitted from a uniform source, having a luminous intensity or candlepower of unity, on to an area of one square foot, every part of which is one foot distant from the source.

much as it is now, we do not believe these values will need to be changed in future years, unless it becomes possible to provide very much greater amounts of light economically. It should be noted, however, that persons over 40 years of age may require higher values than we have recommended. Individual requirements can be met by the provision of desk lights.

Our recommendations agree closely with the current "Code for the Lighting of Building Interiors," issued by the Illuminating Engineering Society of Great Britain.

Adequate light on the work is important, but so also is the way the light is generally distributed. For visual comfort and efficiency it is essential to use lighting units which, without being excessively bright, will light the walls, the ceiling, and the work adequately. In general, the working plane should receive somewhat greater amounts of light than other surfaces. We discuss in detail various arrangements of lighting which will give the desired results, and we note the unsatisfactory features of some forms in common use. We have also described some matters of decoration and furniture finishes which require consideration to ensure that the general gradation of brightness in rooms will be good.

Recommendations are made for the lighting of specific types of offices. We also discuss briefly, wiring and supply pipe installations, noting the method of designing a complete installation capable of lighting a whole floor space, as well as the practice of merely bringing rising conductors to the tenants' meter positions and leaving the tenants to install surface wiring to their requirements. We prefer the former method on various grounds.

LEGISLATIVE ASPECTS

No by-laws or regulations specifically concern the natural or artificial lighting of office buildings except by the limitation of external obstruction.

We note and commend the recent recommendations of the Gowers Committee (14) [1] that the Factories Act (1937) and the Shops Act (1924) should be extended to cover offices. This would mean that offices would be subject to inspection and as a first stage be required to provide "suitable and sufficient lighting."

We have briefly considered the question of prescriptive rights of light and we hope this will be brought under review by the appropriate authorities.

In conclusion, we consider that at the present time national and individual efforts can best be directed to raising the quantity of illumination on the work where it is below the recommended level and to improving the quality of lighting everywhere.

PART I. THE DEVELOPMENT OF OFFICE BUILDINGS

3. During the latter half of the nineteenth century a great demand arose for office accommodation in London and other large commercial centres because of the great expansion of colonial and foreign trade which followed the industrial revolution. Buildings to meet the needs of commercial firms, banks, and insurance interests were usually erected on restricted sites and with a narrow and often elaborate street façade, going up to a height of three or four storeys. Most of these structures were intended for their owners' use only, but even at this early stage it was common for their upper floors to be regarded as lettable office space, and in London provision was made in the Metropolitan Building Act of 1855 for the separation of different tenancies, in buildings over 3600 sq. ft. in area, by a party floor of fire-resisting construction.

4. The fenestration of these Victorian commercial buildings was undoubtedly influenced by the desire for a well-mannered façade. Some slight increase in the proportion of window to wall area was obtained later in some structures by the use

[1] References in parentheses are to the list on page 33.

of a grouped treatment of windows in lieu of the earlier Georgian type of separated windows, but the total net area of the windows above first floor level seldom exceeded about one-third of the total wall area. Notable exceptions occur towards the end of the century, as for instance in office buildings in the City of London designed by Robert Marsh, which achieved unusual standards of daylighting. These buildings were intended for specialized use, however, being chiefly for traders who desired a high standard of daylight for testing and valuing samples of merchandise—they did not represent the general trend of office design. Even at this period, to ensure stable structures, the Metropolitan Building Act of 1855 restricted the total window area above first floor level in any façade to half of the wall area, although it was possible to obtain a relaxation of this requirement if stability could be ensured in other ways.

5. Iron pillars and joists began to be used in the construction of offices in Britain about the middle of the nineteenth century, following their introduction in warehouse structures; but although the windows were often treated as an arcade and closely spaced, their size was affected little by this structural change. About this time it also became customary to supplant the ground floor walls by large shop windows, although the upper walls were still required by legislation to be of stone or good brick. In contrast, commercial buildings in the United States were being erected between 1850 and 1880 with cast-iron fronts and often with cast-iron skeleton frames, and in many of them the structure was so simplified that the iron columns and lintels of the street façade became in effect the intermediate members of one great window.

6. The evolution of the skeleton steel and reinforced concrete structural frames, coinciding with the development of the passenger lift, made possible the provision of office floor space many storeys above the height previously feasible, but did not coincide with any major advance in the arrangement of the windows. In Britain, the placing of windows was still largely influenced by the desire for a monumental façade, while complying with restrictions such as were imposed by the London Building Act. However, from about 1918 onwards more attention was paid to the relation between the interior plan and the formal window pattern, as in the Cunard Building in Liverpool, and from about 1930 office buildings began to be erected which showed a desire for experimentation in the disposition of windows, either in continuous horizontal bands or with a vertical emphasis, as for instance the "Daily Express" Building, Great Westminster House, and 51–54 Gracechurch Street, London. Further development in London towards a complete window-wall was precluded by the London Building Act, in which restrictions were maintained largely to prevent the spread of fires.

7. Although the artificial light sources and fittings have developed along with other improvements in office services and equipment, so far they have had little effect on the planning and general design of office buildings. In America, however, as we discuss later in this Report, supplementary artificial lighting is being deliberately used in some cases to extend the useful zone of daylight and to encourage thereby, if not the windowless office, at least the planning of office blocks much deeper than those to which we are accustomed in Britain. If the office block of the future is going to develop on these lines it calls for a much closer integration of the artificial lighting with the original office design than has been apparent in the past.

8. The present position is not very satisfactory. According to the inquiry carried out for us by the Social Survey of the Central Office of Information (Appendix I) some 7 per cent. of office staffs are working in rooms without windows though the majority of them have skylights or glass screens, and of the remainder more than 20 per cent. received no direct light from the sky on their desks. In other words, about one in five of office staff have inadequate daylight, and in the cities the figure may be even higher.

9. For the future much better conditions are possible. The bombing of the central areas of many of our large towns has afforded great opportunities for a major rationalisation of urban re-development, and the general lines which should be followed are well understood. Our first Report, which dealt, *inter alia*, with daylight in relation to town planning, was published at a time when it served to assist the clarification of ideas and objectives, and there is now substantial agreement on the principles to be observed in the reconstruction of the central areas. Nevertheless it is clear that, for many years to come, a large number of office staffs will have to work in premises where, over considerable areas, adequate daylight will not be available for a substantial part of the working day. While some palliatives to improve daylight may be possible, the main relief in such cases must come from the provision of suitable and adequate supplementary artificial lighting.

PART II. NATURAL LIGHTING

EVIDENCE ABOUT OFFICE DAYLIGHTING

10. Most people agree about the desirability of natural light for work in the daytime, but a few have questioned it recently, especially in America. It seemed to us that it might be useful therefore to review opinions in this country. Accordingly, we have taken evidence from various staff associations and from experienced architects and estate surveyors.

The evidence from representatives of the staff associations indicated that in the majority of cases staff strongly object to working in places wholly without daylight, and it was their view that it was not desirable because it tended to lead to "eye-strain," "nervous strain," and a general lowering of health.

The evidence of the architects and surveyors chiefly concerned economic factors. The Director of Lands and Accommodation of the Ministry of Works said that good natural lighting is one of the factors taken into account by his Department in deciding rental values, and, other things being equal, a higher rent would be considered proper for well daylighted than for poorly lighted space. The architects and surveyors supported this from the point of view of the agent and building owner, and emphasized that the importance attached to good daylighting was in fact increasing rather than diminishing in this country to-day. They said this view had now advanced so far that the top floors were let first, the highest rents often being obtained for them, and that property owners were becoming content to reduce the total floor area of proposed buildings if by this means they could get better daylight.

It must be emphasized that these arguments are not directed in any way against good artificial lighting, which the witnesses supported. There is unquestionably a general desire for better daylighting for daytime work and for good artificial lighting at other times.

THE PLANNING PROBLEM

11. Commercial life in cities is bound to require some concentration of office accommodation in the central areas. Apart from the difficulty of spreading a business district in a mature city, there is a sound economic reason in the convenience it gives for direct business contacts. Unfortunately, traditional urban development does not accommodate the desired densities without serious disadvantages, among which bad daylighting is prominent.

12. In our first Report we described work done by the Building Research Station which pointed the way to an alternative system of development allowing high standards of daylighting without prejudice to density. Subsequently, support was given to these ideas, in particular by the Ministry of Town and Country Planning [1]

[1] It should be noted that Government Departments are referred to by the titles obtaining at the time this Report was written.

and by the Consultants for reconstruction in the City of London. We will not enter here upon a general discussion of the theory and practice of urban development, but a brief review of some main points is necessary.

13. Traditional development consists essentially of buildings erected to a considerable height along the street front and relieved at the rear by so-called light-wells, which served to provide ventilation and some pretence of daylight. For convenience, this type of development has been termed corridor street development.

So far as lighting is concerned the disadvantage of this system is that from the lower storeys the view of sky obtained over the buildings opposite, or over the tops of light-wells, is at such a high angle that daylight cannot penetrate very far into the interior. Efforts were made to preserve reasonable conditions by limiting the height and the angle of set-back, but they obviously had little success. Limitations of height were also brought about to some extent by easements of light, but in an indefinite and irregular manner.

14. The desirable alternative is now well understood. In our first Report we called it "open-planning," and our colleagues of the Business Buildings Committee called it "vertical planning" (15). As a system of design it is difficult to describe precisely, but it has certain characteristics from which the underlying ideas can be understood. For effective development, a reasonable size of site is required, *i.e.* upwards of three-quarters of an acre. Given this area, a building can be formed upon the site with its main mass set back, and so arranged that, from neighbouring sites, views of sky can be obtained over it or past its sides at an angle low enough to allow daylight to penetrate deeply into the building interiors. Light-wells, a familiar feature of traditional development, are not necessary, being in effect placed on the periphery of the building instead of within.

These general ideas can be given more exactness by descriptions of some typical arrangements, and from Plate IV.

15. Of formal developments, perhaps the most obvious is the comb-shaped plan in which arms project at regular intervals from one or both sides of a main spine unit. In this case the sites opposite benefit chiefly from low-angle views of sky seen over the spine unit between the projecting arms. Another formal arrangement is the simple cruciform block, and in this case the neighbouring sites benefit not only from the view of sky over parts of the building, but from views obtained past the sides.

16. Examples of informal arrangements are asymmetrical developments of cruciform units, or T- or L-shaped plans, but of course a great variety of informal shapes which permit low-angle views of sky over them or past their sides is possible. In general, high buildings with high angles of set-back are not objectionable in the system provided that suitable parts of them are low enough to allow some low-angle light to reach neighbouring buildings.

17. There is a very useful secondary effect in this kind of development, because the façades of buildings are brighter than in corridor streets, being more exposed to the sky. Consequently there will be more reflected light entering rooms on the lower storeys.

18. Open planning apparently has other important advantages over corridor-street development. It is claimed that there are reduced risks from fire (3), reductions in noise (4), and increases in the proportion of uncovered land without prejudice to the density of development (1).

19. A vital question is how to give general guidance and control building design to produce these results. The usual practice of the controlling authorities has been to enforce angles of set-back and limitation of site coverage and total height. Something of the same sort is still required but with this difference: the uniform angle of set-back which has been customary is unsuitable for open planning as

it often fails to restrict sufficiently in the right place to ensure any low-angle light, and it restricts too sharply parts of buildings which without harm could be allowed to rise to a considerable height. It is necessary therefore to clarify and extend the system of angular restrictions. This has been done jointly by the Building Research Station and the Ministry of Town and Country Planning (5), and consists essentially in establishing a uniform angle of set-back, giving a certain standard of daylight in an obstructed building when a reasonable size of window is used, and then discovering alternative lower angles of set-back which, if provided over correspondingly limited parts of the sky-line, would ensure an approximately equal standard of illumination. When a designer restricts part of a building according to one of these lower angular restrictions, he has corresponding freedom with the remainder.

20. A simple aid for designers using the alternative angles of set-back is fully described in a handbook of the Ministry of Town and Country Planning (1).

21. The standard of daylight chosen for the original work by the Building Research Station and the Ministry was based on early discussions in this Committee when attention had centered upon a 1 per cent. sky factor provided at a point not less than 12 ft. inside a ground-floor room. It is now known that if sizeable windows are used in office buildings and sites are of adequate size this standard can be obtained without prejudice to reasonable densities of development. That is to say, the densities possible could be as high or higher than authorities in this country are likely to want, and higher, too, than those commonly existing. It must be appreciated that present densities, though they produce congestion, do so chiefly because the wrong type of development is used to accommodate them. With the kind of buildings now envisaged even higher densities than those to which we are accustomed need not produce congestion.

22. We noted that open planning depended on having sites of reasonable size. In war-damaged areas this is not a great difficulty, but elsewhere the existence of small sites, already developed, means that persistent and skilful administrative action will be required to bring these together in the right way in the course of time. The question arises as to which of several possible policies to follow, when all of them have awkward features. One course would be to permit re-building to the prevailing density under the usual restrictions, but this achieves no real improvement. Another possibility is to impose restrictions to ensure good daylighting regardless of density, but this would operate onerously on many of the smaller sites and cause inconvenience and dissatisfaction. The third course is to attempt to bring adjacent owners together and encourage common development or to acquire and hold sites in the public interest until comprehensive development is possible. This last course seems the only reasonable way of utilizing the small sites established by tradition. The other two methods either benefit an owner at the expense of his neighbours' amenity or benefit the neighbours at the expense of the owner. What is required therefore is a full realization of the value of changing the course of tradition and the will to do so.

There will naturally be many modifications of open planning in practice. It does not suit all occupancies, for instance, department stores or warehouses; nor is it necessary in areas intended for moderate densities. All such questions we must leave for consideration by those concerned, and turn now to the problems of lighting which arise inside buildings.

STANDARDS OF DAYLIGHTING AND THEIR COMPUTATION

23. *The size of offices.*—Ideally, the daylighting of a room should be related to its size, but the majority of office buildings are designed for letting (even if the owner intends to occupy them himself at first) and consequently the interior space is treated as a whole and not as if its sub-divisions were determined in

advance. In other words, standards have generally to be related to what may be termed bulk space, rather than individual rooms. Nevertheless it is useful to bear in mind the sizes into which offices are commonly divided.

Typical dimensions are:

Small offices for one, two or three persons; 150–250 sq. ft. in area, 11 or 12 ft. wide and 15–20 ft. deep.

Medium offices for 4–15 persons; 300–900 sq. ft. in area, 15–30 ft. wide and not less than 15 ft. deep.

Large offices for more than 20 persons; upwards of 1,000 sq. ft. in area, often the full depth of the building which is 40 ft. or more, and lighted from both sides.

In practice, the structural bays into which a modern office building is commonly divided act as a convenient planning module and individual offices usually consist of one or more complete bays.

24. *The influence of the type of work.*—Ideally, lighting should be adjusted for the work, but with daylighting it is generally necessary to adjust the work to the light; that is to say, the work which is visually most exacting should be done in the areas with the best daylight, and the easier work elsewhere. In practice, this generally means that typing, accounting, computing, and sustained visual work should be done near windows, leaving general clerical work, intermittent tasks, and filing to the other areas.

Drawing office work is in a special category, and we discuss this later.

25. *Standards for side-lighted offices.*—It is convenient to consider indoor space as roughly divisible into three zones. There is a region near the outer walls where daylight can be sufficient by itself most of the time. Then there is a zone where supplementary artificial light may make the otherwise inadequate daylight acceptable for some kinds of work. Finally, there will be areas where dependence must be placed entirely on artificial light. For the moment we are concerned with the outer zone only and the main questions are how to define its depth and how deep to make it.

One way of defining its depth would be by the location of the no-sky line. For corridor streets, where the obstructions cause the no-sky line to run parallel to the window wall in a straight line a few feet from the window, this might be satisfactory, but with open planning the no-sky line might in places penetrate as deeply as 50 to 75 ft. from the window, and so becomes inconvenient as a reference.

A more reliable way is to establish a suitable sky-factor value and say how far inward the sky-factor contour should lie. This is the method we recommend.

26. First, it is necessary to have the penetration sufficient to ensure useful light to a reasonable number of occupants in a room. In our view this means a penetration sufficient to cover two rows of desks. For modern offices one row of desks could not be regarded as reasonable and, in rooms lighted only from one side, three is obviously impracticable. It follows, then, that good daylight should be expected over a working depth of the order of 10 or 11 ft. It is not convenient to state the requirement in this form, however. Sky factors have to be computed from the outer edge of the window opening, and measurements inwards have therefore to allow for the depth of the wall. It seems prudent also to make some allowance for space occupied by radiators, piping, and similar equipment often placed on the window wall. With all these in mind we have come to the conclusion that it would be appropriate to assume reference points 12 ft. inwards from the external face of the wall.

27. There is no exact basis on which to determine the correct sky factor to associate with the requirement for penetration. Whatever value is chosen would

be exceeded in the area between the reference point and the window, and it is a question therefore of establishing a suitable minimum. Also, a sky factor represents no fixed level of illumination because this changes as the brightness of the sky changes, and therefore the value chosen must be determined on the basis of ensuring reasonable levels of illumination for most of the working day over a reasonable proportion of the year.

Fortunately, there is now available a considerable body of experience on which to draw, and the range of values which has been found suitable for various common purposes ranges from 0·5 per cent sky factor upwards. For instance in our first Report, after careful study, we recommended values of 0·5 per cent sky factor in connection with bedrooms, 1·0 per cent for living-rooms and 2 per cent for kitchens. We also referred to values of 2 per cent and 5 per cent for school classrooms, many of which have subsequently been designed to provide these values at the worst points. Moreover, we have examined a number of kinds of office work and on the basis used in the Illuminating Engineering Society's Code (10) the appropriate sky-factor value is 4 per cent.

We have come to the conclusion, therefore, after due consideration, that the proper value to provide at the reference points is 1 per cent sky factor. This will mean that over a substantial part of the well-lighted zone, sky factors at least as high as 4 per cent will be found, and it will also ensure that the minimum level is generally tolerable. For example, the 1·0 per cent sky factor will mean minimum values of 5–10 lumens per sq. ft. during much of the year, and it will be seen later that this is of the same order as the least value we think desirable for the artificial lighting of intermittent office work.

28. There are certain consequences of the recommended standards which must be mentioned:

First, there is the question whether they make necessary either excessively large windows or unreasonably low-density developments. Neither need be the case. If the ground floor be taken as a convenient reference level, windows with lintels 10 ft. above the working plane (5), which are not exceptional in densely developed areas, will admit the standard illumination and yet permit densities of development which are acceptable for urban planning, always assuming of course that the sites used are not too small. For instance, if moderate sized sites are used, a floor space index, *i.e.* ratio of floor space to site area, of 2·5 is possible, and on larger sites an index of 3·0 is possible without going up to more than ten storeys. Such values exceed present values in this country except in a few places.

While the ground floor seems the sensible one to use for common reference and comparison, the floors immediately above are often the most difficult from the point of view of natural lighting. It used to be the case that the heights of upper floors were graded for architectural effect and to compensate for reduced lighting in lower floors. Perhaps the tradition has lapsed because it is so ill-rewarded in ordinary corridor streets. In open-planning it can be well worth while, and make possible the proposed standards without resort to excessive windows.

In making computations, where the obstructions are regular the easiest course appears to be to compute the factors at critical points along the line 12 ft. in from the outer wall face and then to adjust the window-head to give the required value. Where the obstructions are irregular it is likely to be more convenient to compute from two or three points in line back from the window.

29. In applying the recommended standards to a proposed design the daylighting of each office is not computed, if for no other reason than that as a rule the internal layout is not known in advance. This enormously reduces the work to be done, because only simple computations for long rows of windows are needed to ensure a 12 ft. belt of properly daylighted area around the lettable spaces. It is true that sub-division will reduce the penetration in individual rooms slightly; for instance, in an office 12 ft. wide the 1 per cent contour would lie about 10 ft. from the

external face of the wall instead of the recommended 12 ft.; but we do not think this will have any unfortunate effects in practice and will only be important on the lower floors (see Figs. 1 and 2).

30. *Offices lighted from overhead.* There is no kind of office work for which overhead lighting is essential, though it is desirable for drawing offices and is very convenient because of the uniform distribution of light and high intensities obtainable. Work on drawing boards requires high intensities such as would only be found near the windows when side lighting alone is possible. A minimum sky factor of 5 per cent would be a reasonable figure to use for the design of top lighted offices. Even so, for some part of the day, and over a large part of the year, many drawing office tasks will still require the daylight supplemented to maintain the minimum values we recommend for artificial lighting alone.

THE DESIGN OF WINDOWS

31. Windows like other light sources can cause glare, and such conditions may give rise either to visual discomfort or disability or both, as described more fully in paras. 56–58. Visual discomfort causes tiredness, and visual disability, as the term implies, causes reduced visual discrimination. Good window design can be described as the technique of admitting enough light without causing discomfort or disability. Freedom from these faults is to be found essentially in freedom from excessive contrasts on, or immediately around, the windows and freedom also from deeply shadowed areas in the room. It depends on the right kind of window surround and on the position of the windows in relation to the room.

32. Many successful methods of dealing with these effects have been evolved in the past and it is necessary to find methods of reaching similar, or preferably better, standards than were attained by the best of traditional work.

The chief points to observe are the following:

Window bars should be infrequent, slender, and tapered inside to prevent a wide shadowed face.

The main frames should be designed to show the minimum of shadow by making them narrow, by splaying them, or building them in.

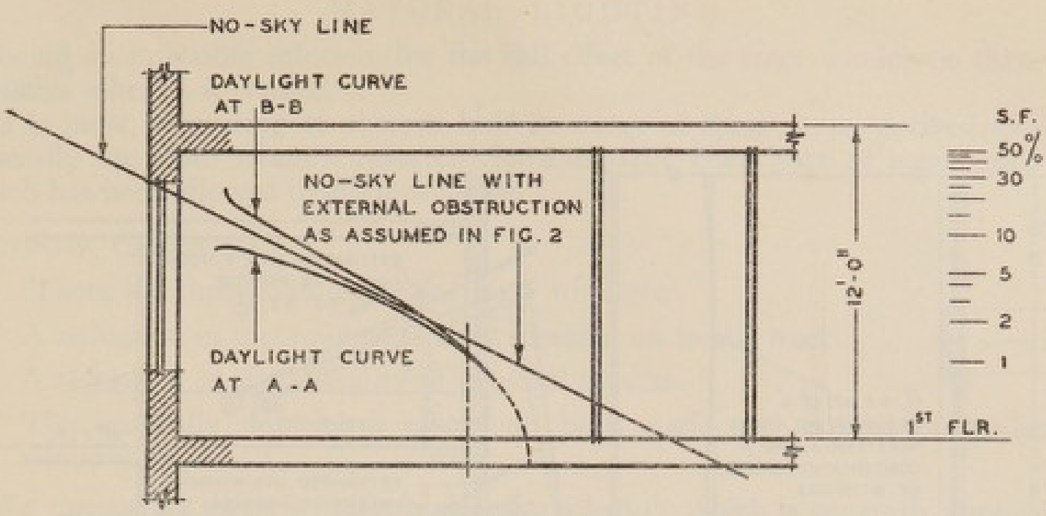
Bars and frames should be finished internally in white or very light colours.

The contrast between the interior and visible sky should be further reduced by finishing the external and internal reveals and soffits in white or light colours. This helps to provide an intermediate zone of brightness between the shadowed interior and the bright sky and is typical of many excellent Georgian windows.

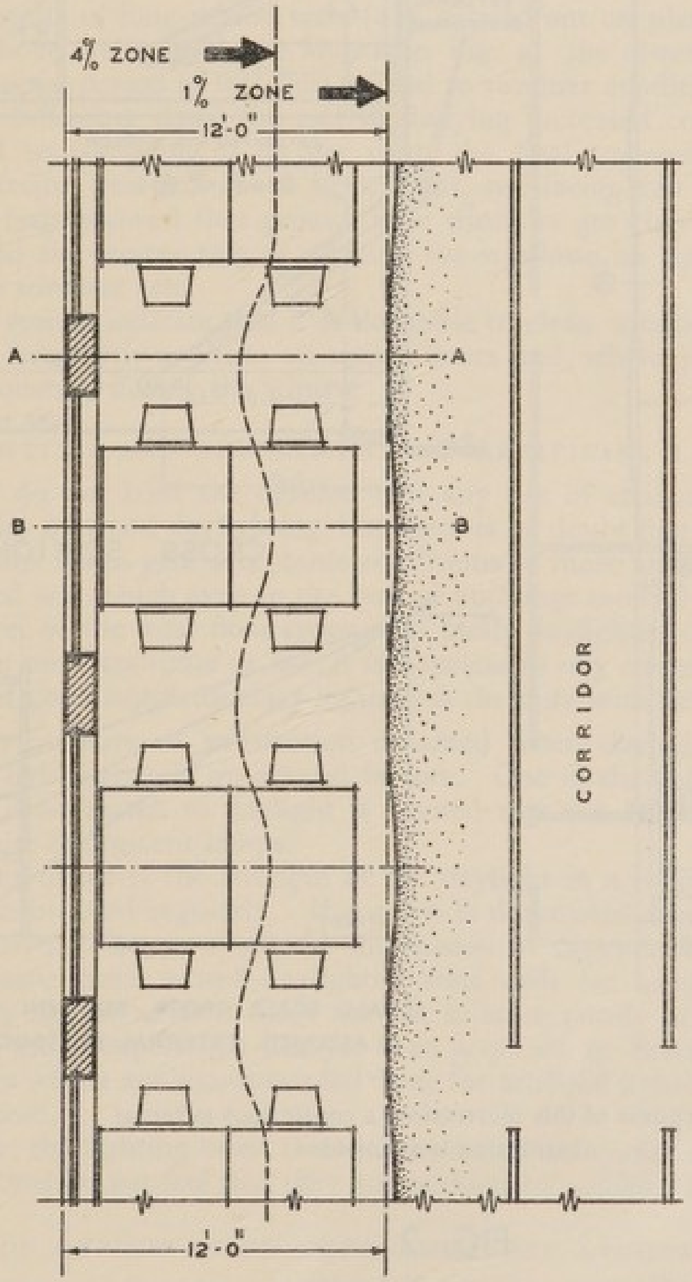
Deep lintels should be avoided, and there is something to be said for small external canopies or widened external soffits to help to reduce the sharpness of contrast. The greatest contrasts tend to occur at the top of the window where the visible sky often appears brightest and the soffit of the lintel is in shadow. This condition is aggravated when there is a deep lintel with full shadow on its inner face.

By all these methods the adverse effect of internal shadowing can be minimized and together they help to produce a pleasant sensation of lightness and visual comfort in office interiors.

33. There is an additional point we must mention when very large and high windows are used. On days when the sky is bright there will be both discomfort and disability, even when contrasts are low. The only way to counteract this is to reduce the effective brightness of the sky. Ordinary blinds are useful and venetian blinds or other louvre systems may be better. Another possibility is to use tinted glass, as in a recent American building, but this has the disadvantage

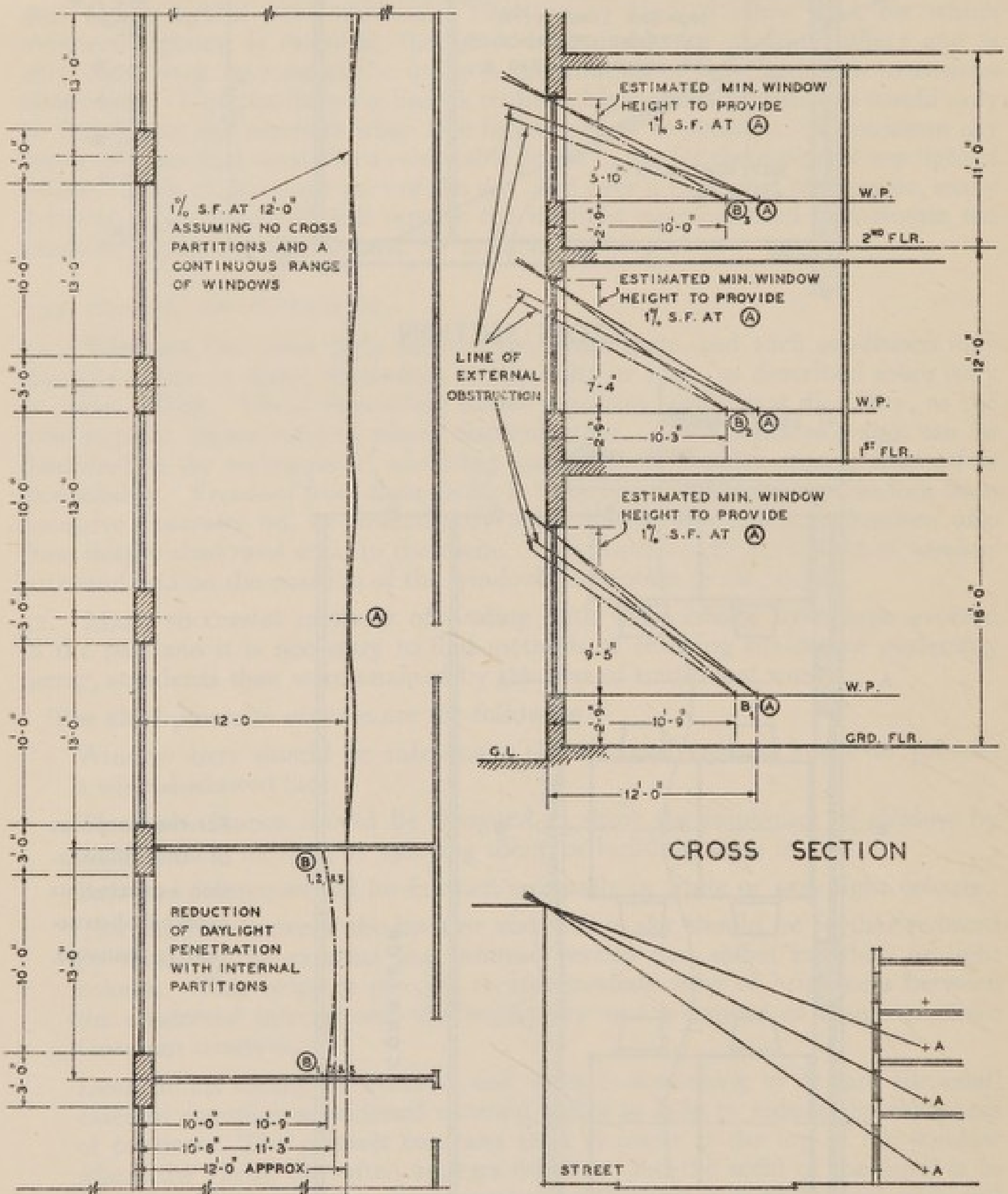


CROSS SECTION



For the purposes of this illustration a continuous external obstruction is assumed.

FIG. 1. PLAN



PLAN

SMALL SCALE CROSS SECTION SHOWING ASSUMED EXTERNAL OBSTRUCTION

For the purposes of this illustration, a continuous external obstruction is assumed.

FIG. 2

of being an inflexible solution, for the full effect of the large window is then not available when it is wanted.

It is most interesting to observe how so many of these ideas, derived as they generally are from modern research, have actually been part of some tradition which has been allowed to fall into disuse.

WINDOW CLEANING

34. There are three main effects of dirty windows:

A reduction in the amount of light directed on to the work.

A reduction in the visibility of external objects.

The generally unpleasant effect, on both staffs and public, of neglected windows.

We cannot lay down a uniform cleaning schedule which is generally applicable, but the following brief account of some tests will indicate points to watch when arriving at sensible routines for individual cases.

The results of long-period tests (21), carried out on plate glass windows about 100 ft. above street level, are shown in Fig. 3: the observations began in April and the initial period of test thus related to summer conditions. From November until the following April the rate of dirtying increased considerably. Assuming an initial transmission of 80 per cent, the final transmission of an uncleaned window facing west was about 53 per cent, and facing east 48 per cent.

Other tests showed that ground floor windows get dirty about twice as fast as others and the winter rate of dirtying for windows on upper floors is about 1·3 times the summer rate.

These results indicate that it is desirable to clean windows on the ground floor twice as frequently as those on upper floors and, where practicable, all windows more frequently during the winter.

DAYLIGHTING AND SUPPLEMENTARY ARTIFICIAL LIGHTING

35. We do not hold the opinion that any use of artificial light diminishes the desirability for good daylighting, but there is no doubt that with properly designed installations it can give acceptable conditions to those areas which cannot be fully daylighted and which even in the best of buildings must always form a substantial proportion of the total floor space. In badly daylighted office buildings, most of which we must continue to use, it is hopeless to rely entirely on natural light, and the use of good supplementary lighting is the only sensible course.

36. The measure of satisfaction obtained when daylight is supplemented by artificial light depends on several factors. One is the colour of the source, and where a close match to daylight is wanted this can be successfully provided by using white fluorescent lamps.

Another factor is the strength of the daylight in a room where supplementary light is to be used regularly. If a room is dominated by a well-daylighted zone it is relatively easy to avoid the impression of dependence on artificial lighting. At the same time, a well-daylighted zone calls for adequate intensities in the artificially lighted areas if these are not to seem poorly lit. This is not a matter in which much experience has yet been acquired in Britain, but we believe the intensities which are recommended later for artificial lighting will be adequate for this purpose.

Finally, the lighting units themselves should be unobtrusive, so that occupants of the rooms do not feel that they are working by artificial light.

DEPTH OF OFFICES WITH SUPPLEMENTARY LIGHTING

37. Where supplementary artificial lighting is acceptable for daytime use it is important to consider how it affects the depth of the zone which can be made

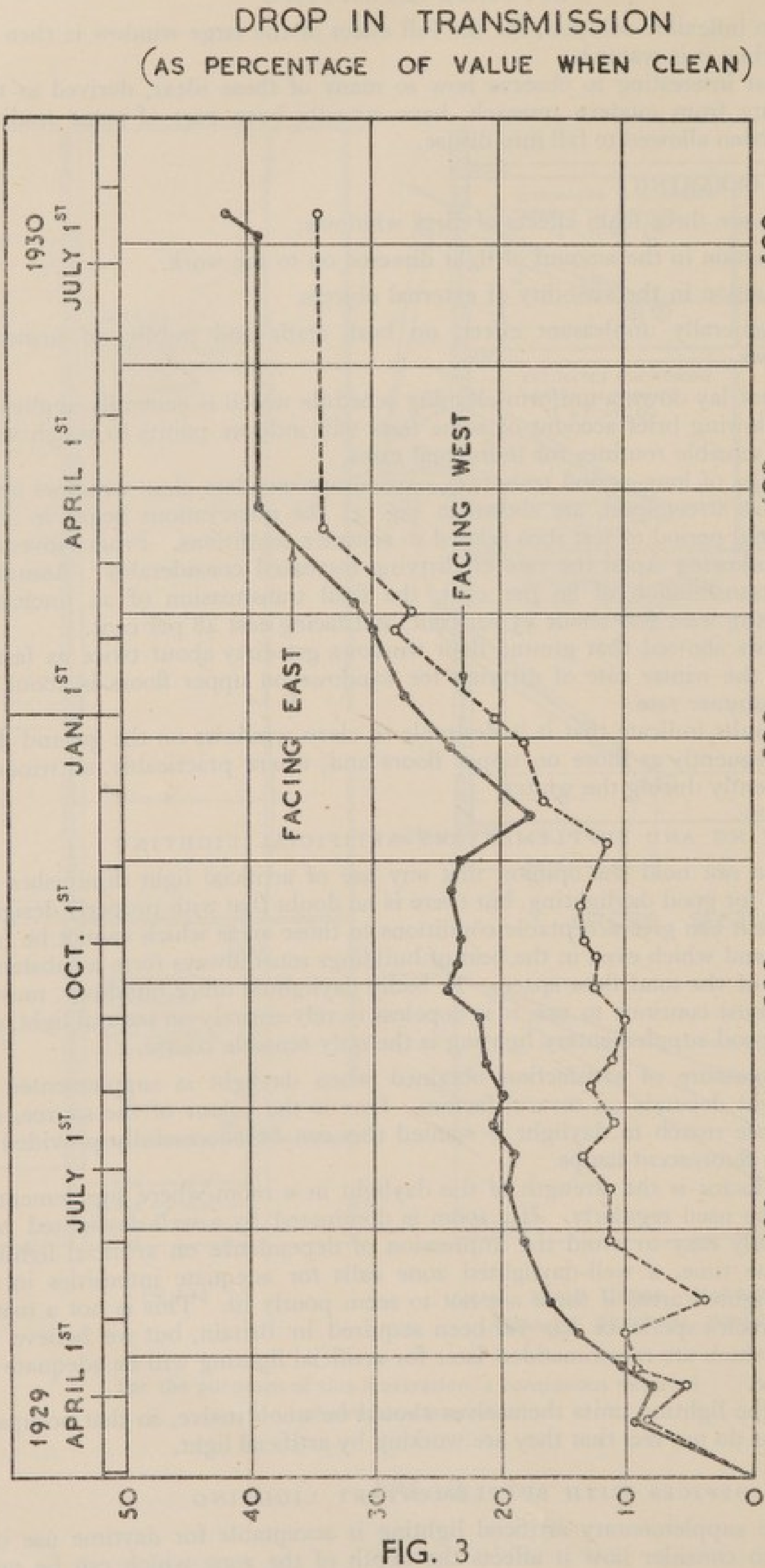

DROP IN TRANSMISSION
(AS PERCENTAGE OF VALUE WHEN CLEAN)
1929
APRIL 1ST
JULY 1ST
OCT. 1ST
JAN. 1ST
APRIL 1ST
1930
JULY 1ST
FACING EAST
FACING WEST
TIME IN DAYS
0
100
200
300
400
500
50
40
30
20
10
0

FIG. 3

to appear well daylighted. Evidence varies, but if the directly daylighted zone is about 10 ft. wide, it is our view that at least another 10 ft. could be made to seem well lit, and experience may show that this figure can be increased.

SUNLIGHT

38. Our evidence about the sunlighting of offices can be readily summarized. Those concerned with the design of offices and those concerned with letting did not feel that sunlighting is an important factor, but in the Survey the staffs made it clear that they like sunshine and want it. The only evident qualification was the fairly obvious one that, in southward facing offices, blinds of some kind were necessary.

Fortunately, as we showed in our First Report, the admission of sunlight is another matter on which open-planning has the advantage over traditional development, and it is our view that architects should in practice take it into account as far as is practicable.

PART III. ARTIFICIAL LIGHTING

GENERAL REQUIREMENTS

VISUAL DEMANDS IN OFFICE WORK

39. We have pointed out that the admission of daylight cannot be related closely to the type of work, but artificial light can be made to serve exact requirements and it now becomes desirable to consider the precise nature of office work.

40. The factors which determine the severity of office tasks are:

The size of the finer details of the work.

The contrast between those details and their immediate background.

The sharpness of definition of the work.

The overall brightness of the work.

In general, the smaller the detail and the lower the contrast the more light is required to do the particular task efficiently and with comfort. A detailed consideration of the principal office tasks will show how these factors are involved.

41. First we may consider the common act of reading, which consists essentially of recognizing the individual shapes of the characters while scanning them in groups. Easy recognition of the characters depends on their definition (blurring increases the difficulty very greatly) and upon their shape, size, and contrast with the paper, in all of which office work is highly variable. For instance, pencil drafts on buff paper offer singularly poor contrasts, especially when the pencil marks are shiny. In addition, written characters are often badly formed and the writing small. Carbon copies of typescripts have reasonable contrasts but poor definition. Tables of numbers may be clearly printed but very small. Obviously some of these things—pencil drafts, for instance—are matters that office managements may be able to avoid; but they cannot avoid much of the variability in ordinary clerical work, and this is one of the arguments for adequate amounts of light.

42. The chief visual problem in typing appears to be similar to that in ordinary reading. Typing is done mainly by "touch" and the reading of notes and manuscripts is the real visual difficulty, although in addition the way in which light falls on the typewriter often affects the convenience and comfort of its operation. Thus awkward shadows across machines and note books, and too much sparkle from bright parts of the machines, can be irritating.

43. The operation of comptometers, calculators, and other office machinery appears similar to typing at first glance, but is essentially different and visually more difficult. For instance, the punching of the keyboard is much less automatic and over long working periods often involves considerable strain in locating the correct keys in the correct columns, checking the numbers and reading the answer, all of which are additional to the initial reading of the data. A similar kind of strain is often experienced if large tables of figures are set up so that location of individual numbers is difficult. In both of these kinds of work quick responses are an obvious factor in the rate of working and adequate light is clearly important.

44. The severity of the visual tasks in drawing offices is much greater than in ordinary clerical offices; the reasons for this are:

Much of the work consists in drawing fine lines with a hard pencil and these are difficult to see on account of their faintness.

Great accuracy is required in the location of lines and the centering of drawing instruments, and this involves a high degree of visual acuity together with concentration of the gaze for relatively long periods upon small fields of view at close range.

It is frequently necessary to read finely divided scales and to adjust drawing instruments with precision.

In making tracings, visibility of the faint lines on the drawings is seriously reduced by the imposed tracing cloth or paper, and close inspection is needed constantly to detect and trace the details accurately.

For these reasons, a high level of illumination is required. The illumination must be sufficient to enable fine detail of low contrast to be seen without bringing the eyes so close to the work that the ocular muscles are over-taxed in focusing and converging the eyes.

45. Much clerical and drawing office work can and should be made easier to see. For instance, blue, green, and grey coloured paper and filing cards make poor backgrounds for ordinary pencil, ink, or typescript because colour and brightness contrasts are unsatisfactory; pencils—and especially indelible pencils—can make sustained clerical tasks unnecessarily difficult. Typing from manuscripts can be assisted by sloping note holders. The more opaque tracing and detail papers should not be used for tracing from fine and intricate drawings.

Typesetting is outside the control of most offices but a great deal could be done, for instance in the setting out of tables and the use of type as large as is practicable, to make reading less tiring.

Some of the feeling of strain that is experienced at the end of a working day may well be due not to the work alone but to environmental conditions such as the presence of glaring light sources and unsatisfactory distribution of the light. This will be considered further when we discuss the design of installations.

VALUES OF ILLUMINATION ON THE WORK

46. It is possible to see most of the things that have to be seen in office work with widely different values of illumination. In daytime, at a given place in any office, the amount of illumination on the work varies considerably. Moreover, in different offices, substantially different values of illumination by artificial light are in use for similar tasks, as shown by the Survey made for us. There is, however, little doubt that the comfort and efficiency of those who work under the lowest values of illumination found in current practice are inferior to those of persons who work in the better lighted offices. Adequacy for efficient working is therefore the criterion for which values of illumination can be most confidently recommended.

47. We have considered especially the results of investigations which were made under the ægis of the Department of Scientific and Industrial Research and of

the Medical Research Council, expressly to obtain basic data which can be applied to formulate practical standards of lighting. These investigations were concerned with the relations between illumination and efficiency in typesetting, where the principal visual task consisted in reading manuscript comparable with much of the reading matter involved in office tasks; the study of the daylight illumination necessary for clerical work; and investigations of the relationship between illumination and efficiency in doing tasks involving the perception of detail similar in size and contrast to office work (7, 8, 9). We have examined a number of typical office documents and determined the range of size of critical detail and the contrast values encountered so that we can apply the results of the investigations mentioned. (See Appendix IV.)

48. On this basis, we are satisfied that the value of illumination on the work for book-keeping, typing, computing machine work, filing, cashiers' counters, and other general office tasks, where the work is sustained over long periods, should be of the order of 20 lm./sq. ft.[1] We realize, of course, that in large general offices there may be areas where work is done intermittently and is visually not very exacting, so that a lower value of illumination would suffice. In such areas the maintained illumination should not be less than half the value we recommend for the areas regularly used for the named office tasks, or for any others which are similarly exacting.

49. In drawing offices, where the work is very exacting, substantially higher illumination is desirable on drawing boards than on the common objects of view in general offices; we therefore recommend an illumination of at least 30 lm./ sq. ft. and, where the work is particularly fine, this should be increased to 50 lm./sq. ft. or more, as described in our recommendations for specific rooms (pp. 27, 28).

50. In private offices, where much of the occupant's time may be devoted to interviews rather than to sustained "close work," general illumination to a value of the order of 15 lm./sq. ft. on the horizontal plane at desk level is adequate.

51. For inquiry offices, reception rooms and waiting rooms, crush and entrance halls, we recommend that the illumination should not be less than 6 lm./sq. ft.

These recommended levels of illumination conform closely to the current Code for the Lighting of Building Interiors issued by the Illuminating Engineering Society (Gt. Britain), and it follows that we endorse the I.E.S. Code so far as these recommendations for office lighting are concerned.

52. The values of illumination which we recommend permit high though not maximum visual efficiency to be attained. We think, however, that so long as the visual demands made by the varieties of office work to which our recommendations refer remain substantially what they are now, our recommendations need not require change, unless much higher illuminations can be provided satisfactorily and economically having regard to the requirements of other amenities such as heating and ventilating. Our opinion therefore is that national and individual efforts can now be best directed to raising the quantity of illumination on the work in those installations where it is below the level we recommend, and to enhancing the quality of lighting everywhere.

There are three other matters to which we would call attention:

53. First, it should be understood that although definite numerical values of illumination are recommended, some variation is inevitable in practice. Higher values are visually advantageous, while values which are not more than 20 per cent lower than those specified are allowable in some parts of rooms. However, installations should not be designed deliberately to provide less light than the values mentioned.

54. Second, it is known that as age advances, especially from the fourth decade onwards, the illumination level necessary to facilitate "close work" rises pro-

[1] See footnote on page 6.

gressively. Persons over forty years of age are therefore likely to be assisted by higher values of illumination than we have recommended. When necessary, individual requirements can be met by the provision of desk lamps.

55. Third, as discussed in greater detail below, if there are glaring light sources in the field of vision, or if the general surrounds of a local working area are relatively very dark, or very bright, discomfort is produced and the efficiency of vision is lowered (16, 17, 18). If these conditions are present they will reduce the effectiveness of the illumination. The values of illumination which we recommend therefore should not be obtained by any means which will detract from their efficacy; that is to say, they must not be secured by the use of inadequately screened sources, nor solely by local lights.

BRIGHTNESS OF THE SURROUNDINGS

56. The realization of the need to consider the lighting and resultant brightness of the whole environment rather than that of the working plane alone is a significant advance in the practice of lighting. It is based on what is known about the behaviour of the eye when subjected to various conditions of brightness-contrast of which the more extreme are generally referred to as "glare." In particular circumstances these conditions of contrast can cause direct disability to vision, or can cause visual discomfort, and in some cases both effects may be present together. Such phenomena are commonly known to lighting engineers as "disability glare" or "discomfort glare" respectively. They can be avoided in the first case by maintaining a satisfactory relation between the brightness of the surroundings and that of the working plane. The best conditions are achieved when the surroundings have a general brightness somewhat less than the brightness of the work. In practice this means that surfaces immediately around the work, *e.g.* the tops of desks, and in the lower part of the room should not be greatly darker than the work, *i.e.* very dark colours and dark shadows are undesirable. Conversely it is undesirable to have the surroundings brighter than the work, *i.e.* neither in very much lighter colours nor much more strongly illuminated than the work. The effect of having the work appreciably darker than other things in view around it is to make the work seem inadequately lighted.

57. The adverse effects on visual performance and comfort which arise from surroundings that are too bright arise also from the presence of bright light sources in the field of view. The effect on visual performance is different from the effect on comfort. The former depends chiefly on the total intensity, *i.e.* the candle-power, of the light sources, and is relatively little influenced by their brightness. The effect on comfort depends on both the intensity and the brightness of the sources. Thus a large source of low brightness may cause little or no discomfort but may cause visual disability; and a small source of high brightness may cause no disability but may be distracting and uncomfortable. Placing a source high up out of the general line of sight will reduce the degree of disability, but it will not always relieve the discomfort.

58. Visual comfort is also affected by the general contrast pattern and local gradations of brightness. Very uniform contrasts can result in dull and uninteresting lighting, but harsh contrasts can cause discomfort and may even distract attention from the work. It is therefore sound practice to use light colours on the ceiling and window walls so that when looking towards the light sources the contrasts are minimized. Sharp local changes in brightness may also be more unpleasant than gradual changes, and visual comfort can be aided by making the change from one brightness level to another in several steps. This is termed "brightness grading." Thus lighting units which grade from bright central parts to darker edges may appear less uncomfortable than uniformly bright sources giving out the same amount of light. Similarly it is desirable to paint windows and the surrounds in white or very light colours.

From the foregoing it is therefore clear that there are three kinds of brightness relationship to be controlled; those on and immediately around the work, those throughout the entire field of view, and those on and around the light sources. Obviously these points will affect the choice of lighting units, decorations, and furniture.

LIGHT SOURCES

59. In our earlier Report (6) we mentioned the artificial light sources in general use in this country, *i.e.* electric lamps, both of the incandescent and discharge types, and gas mantles of the high- and low-pressure types, and our comments about these still apply. In view of the rapid development of fluorescent lamps since the war and their wide adoption for industrial and office use we have considered it desirable to include further information about them in Appendix V. In doing so we do not wish to imply that the other sources should be superseded. The effective utilization of any artificial light source depends very largely upon the design of the fittings and of the general installation, and if this is unsatisfactory any adherent advantage of a particular type of light source will be reduced.

THE LIGHTING UNITS

60. Lighting units are classified according to the manner in which the light from them is distributed. The classification adopted in our previous Report (p. 120) (6) is a convenient one, and Fig. 4 showing a typical unit in each class and the corresponding light distribution curve is reproduced from it.

61. In the direct lighting unit nearly all the light is emitted below the horizontal and consequently the proportion of light directed on to the working plane is high; but if a room is lighted entirely by such units the upper part is often very dark and shadows are very heavy. The unlighted ceiling often contrasts very unpleasantly with the objects on the working plane and still more with the unshaded parts of the units themselves and thus creates conditions which we have already described as undesirable.

62. At the other extreme, indirect types of units throw most of their light upwards and in comparison with the bright ceiling the working plane often seems poorly illuminated.

63. There are special circumstances in which either direct or indirect units may be used successfully, but in general, units of an intermediate type will be most suitable for offices. More explicitly it is desirable to employ units which direct the main proportion of light downwards on to the working plane but also emit a moderate amount of light sideways and upwards. The exact distribution of light is not critical, but probably some 50–60 per cent downwards will be suitable, with 20 per cent or more sideways, and some 10–20 per cent upwards to provide the necessary brightness on upper walls and ceilings.

64. The amount of light emitted sideways greatly influences the design of lighting units. The problem is to light the walls adequately and reduce the shadowing around furniture without causing the unit itself to become excessively bright. As a general rule, in rooms with light walls and ceilings, a higher surface brightness in the unit can be tolerated than in those rooms in which the units are seen against dark surfaces. Recent experiments carried out at the Building Research Station have yielded quantitative data on the relation between the brightness of the lighting unit and the brightness of the surroundings for different degrees of visual comfort. For example, under average conditions a ratio of the order of 30 : 1 between the brightness of the unit and that of the general surroundings produces a condition which may be described as acceptably free from discomfort. As noted above, these experiments have also shown that some reduction in discomfort is gained if lighting units display a gradient of brightness instead of a uniformly bright surface

so that the contrast between the edges of the unit and the immediate background is reduced.

65. The mounting height of lighting units has some bearing on their tolerable brightness. Generally, it is desirable to avoid low mounting heights because the units obtrude too readily into the field of view, but they must be a reasonable distance from the ceiling if the distribution of light on to it is not to be too patchy. Well-designed units not visible within an angle at the eye of 135° from the perpendicular to the floor are unlikely to be major sources of discomfort.

These matters are discussed in some detail in the Illuminating Engineering Society's Code (10). In view, however, of the work at the Building Research Station (18) we feel that it is necessary to emphasize that the values of the permissible brightness of lighting units specified in the Illuminating Engineering Society's Code should be regarded as absolute maxima. This is especially true

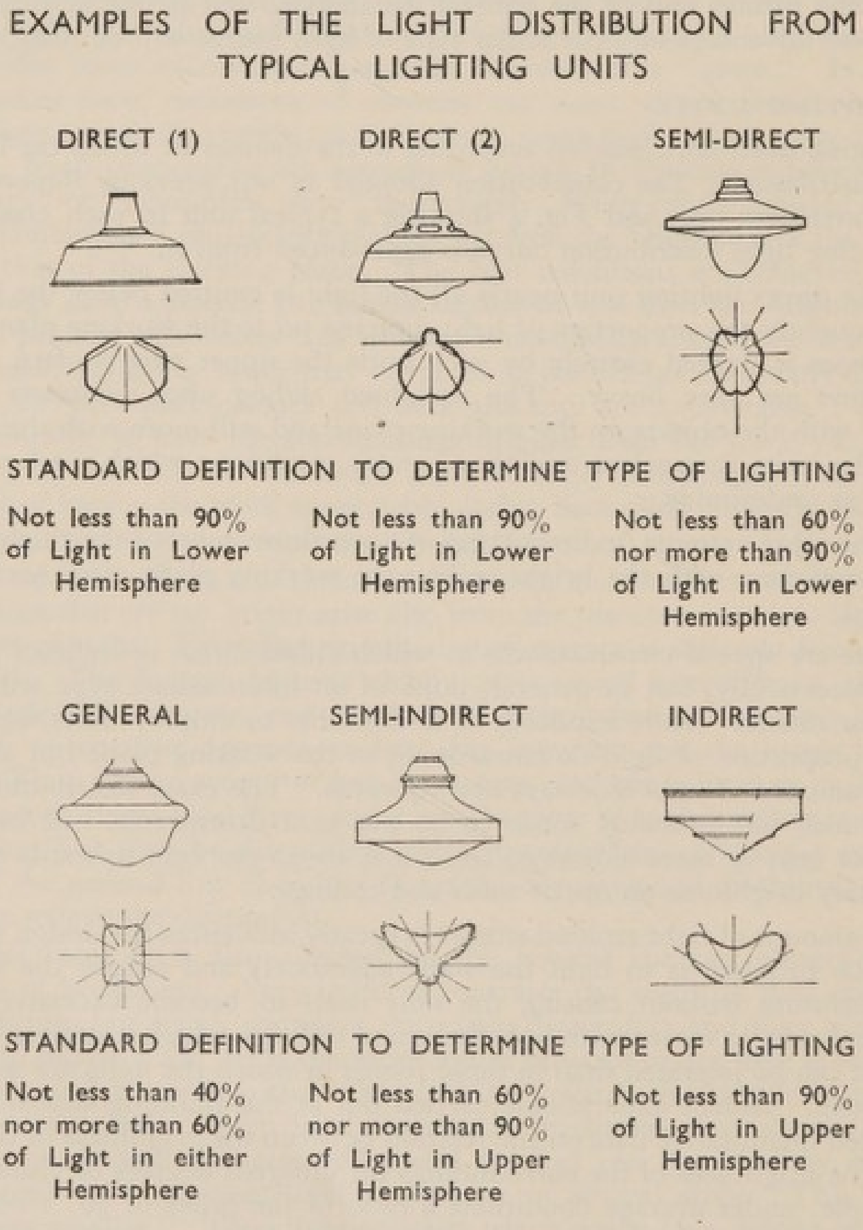


FIG. 4

for large lighting units, because the apparent area as well as the brightness of the unit governs the degree of discomfort from glare. Wherever possible, the brightness of lighting units should be lower than that given in the Code.

66. It is not possible to review individual types of lighting unit, but some comments on one or two well-known types may serve as useful illustrations.

Translucent spheres have been very popular and have often been found acceptable for moderate values of illumination. Present values of illumination require high wattage lamps, however, and the totally enclosed spheres are now commonly found to be too bright for comfort, unless larger units are used to bring the surface brightness down to a tolerable level. Units which emit less light sideways and somewhat more downwards are now considered more appropriate for general use.

67. Much the same comments apply to fluorescent lighting. The bare lamps are too bright in most circumstances to be used without some form of screening. It must be said also that too many of the units now on the market emit too little light upward, but designs are steadily improving.

68. A special note seems desirable about a development commonly called the "louverall" ceiling, which consists essentially of large areas of crossing louvres (egg-crate fashion) forming a ceiling, with the light sources mounted above. It has found popularity for some purposes in the U.S.A., but experience seems to show that it has disadvantages for offices. Apparently there is considerable reflected glare, and because of the large numbers of lamps used to ensure uniform brightness of the louvres, it is difficult to avoid seeing their reflections.

MAINTENANCE

69. It is most important to clean lighting units regularly and to replace lamps before they actually fail. Deposits of dust and the natural deterioration of lamps and gas mantles by use is a gradual process and unless proper arrangements are made the light output from the units is often seriously diminished before anything is done. A good practice is to get a service engineer to make inspections with a light meter at least three times a year to ensure that the intended values are maintained.

It is clearly important for the units to be accessible and easily cleaned; otherwise cleaning is expensive and neglected.

DECORATIONS, EQUIPMENT, AND FURNITURE

70. Dark and dirty decorations restrict the amount of light in a room because they absorb so much of it. They have a bad effect also upon vision and visual comfort because they increase contrasts with the light sources, and can also reduce the brightness of the surrounds too far below that of the work and thus upset the brightness distribution in the field of view and make illumination, which is otherwise adequate, seem poor and unsatisfactory. They are also depressing for people who use the rooms. The inquiry made by the Social Survey showed that the walls of most offices had a reflectivity of less than 50 per cent, and about one-seventh of office staffs worked in rooms with reflection factors below 20 per cent, which indicates that the importance of satisfactory reflection factors is not as widely recognized as it might be.

71. In principle, the problem is to get an acceptable balance between the brightness of the light sources and their immediate surroundings in the upper parts of the room, and between the work and its immediate surroundings in the lower part. The problem of getting a reasonable brightness ratio between lighting units and ceiling is commonly resolved by making the ceiling white or nearly so. It is not always easy to reduce the brightness of lighting units to entirely satisfactory levels and a white ceiling is then a wise precaution. As already noted, the lighting units should deliver a reasonable amount of light to the ceiling, and if this is not done the white surface will lose much of its value.

72. If colours are to be used on ceilings the fact that they have lower reflection factors than the customary white ceiling means that special attention should be given to the brightness of the lighting units and the amount of light reaching the ceiling. As a general rule, colours with a reflectivity not less than 70 per cent should be used.

73. The brightness of walls must to some extent be a compromise. Light colours are usually desirable for good distribution of light, but there is something to be said for keeping the reflection factors within a slightly lower range than is often advocated at the present time. Such practice is likely to allow more satisfactory brightness ratios between the walls and the generally lower brightness values of furniture and people, and it opens the way to a more colourful range of finishes than the customary de-saturated wall colours. Reflection factors of the order of 60 per cent will often be most satisfactory for this purpose.

74. The window wall is often worth treating as a special case by giving it a higher reflection factor because it is the surface seen around sources of light. In all cases, as previously recommended, it is important to have the window frames and reveals white or in very light colours. Where the window looks out upon a dark view this treatment is less necessary.

75. To a large extent, floors have to be chosen for other characteristics than their surface brightness, but it is well understood that lighter coloured floors are conducive to more comfortable visual conditions. Reflection factors not less than 15 per cent are desirable and often obtainable merely by cleanliness and good maintenance.

76. Office papers are generally light in colour and it is not difficult therefore to ensure that the work is brighter than the immediate surroundings. The problem is usually the reverse inasmuch as furniture is often too dark and there is often too much shadowing in and around it. Furniture with light finishes should generally be used and such treatment should extend to desk tops, which should be as light as practicable to avoid too vigorous a contrast with papers on them. Surfaces with a reflectivity of 35–40 per cent are desirable.[1]

77. Another matter which affects the choice of suitable finishes for furniture and office equipment is the glare which may be caused by reflections of the light sources on desk tops or other surfaces. The effect is often disconcerting and unexpected. The worst reflections occur from shiny dark surfaces, such as highly polished black glass desk tops, which can reflect a mirror image of the bright parts of the lighting unit above, with maximum contrast between the image and the surrounding dark surface. Often an additional annoyance is the fact that to the eye the focal distance of the mirrored image is much greater than that of the adjacent work and reflecting surface.

78. Reflected glare from the work itself is often annoying and may occur from a multiplicity of reflections from bright parts of typewriters and computing machines and from the sheen on paper. The two main ways of avoiding reflected glare are the use of light coloured surfaces and matt finishes, but the right kind of ceiling conditions also help. It is just as important to reduce reflected glare by avoiding unscreened sources and uneven light distribution on the ceilings as to minimize direct glare.

THE LIGHTING OF SPECIFIC ROOMS

79. We have discussed the principles which affect the design and installation of suitable lighting units. It remains to discuss their application to individual rooms and to mention some of the practical points which arise.

[1] It is understood that a British Standard is in course of preparation which will give guidance on the reflection factors of representative colours. Also a few paint manufacturers now include reflectivity factors in their trade publications, and others are prepared to supply information.

80. The heights from floor to ceiling in offices do not as a rule exceed ten or eleven feet, so that with correctly designed lighting units, adequate illumination on the upper parts of walls and ceilings may be obtained without the difficulty sometimes encountered in factories and workshops with high ceilings. The main differences in the lighting of offices arise from the variations in the work and in the overall floor areas of rooms. As a general rule, there is more risk of visual discomfort in large rooms with the customary types of lighting units because of the large number of units involved and the difficulty of screening some types of unit from the direct view of all staff. On the other hand, for large rooms with flat ceilings, where the illumination on the working plane is not required to exceed 20 lm./sq. ft., it is advisable to avoid completely indirect systems owing to the risk of glare and distraction from the large area of bright ceiling viewed at a low angle. As previously mentioned, in comparison with the bright ceiling the working plane may often seem poorly illuminated. In certain circumstances, for instance, board rooms and entrance halls to banks, indirect lighting systems may be appropriate, but they are costly and need to be done skilfully if they are to succeed.

SMALL PRIVATE OFFICES

81. In offices for occupation by one or two persons, where it is often possible to design for fixed desk positions, the lighting is less of a problem than in large general offices because the types of lighting units which are liable to cause discomfort glare can be more suitably placed in relation to the desks. As the office tasks may range from interviews to prolonged study of reports and other documents in fine print, flexibility in the level of illumination is often advantageous. As an alternative to a general illumination of 15 lm./sq. ft., therefore, a minimum general illumination of 10 lm./sq. ft., with local lights to provide the additional illumination required on the desks, is sometimes preferred.

GENERAL OFFICES FOR TYPING, COMPUTING MACHINES, AND CLERICAL WORK

82. It is in large general offices for clerks and typists that rearrangements of desks due to changes in staff and office routine are most likely, and this emphasizes the need for a good general lighting with uniform distribution throughout the whole room to make such changes convenient.

Where sustained work is expected, installations should be designed to provide a minimum value of 20 lm./sq. ft. at working level without causing awkward shadows across ledgers and note books or giving rise to glare from specular reflection on the polished parts of typewriters and computing machines. In offices used for typing or computing machines only, a general illumination of lower value can be provided by overhead units, supplemented by individual desk lamps to provide the additional illumination required on the work.

As mentioned earlier, the use of computing machines is different from typing and is visually a more difficult task. We recommend, therefore, that particular attention be paid to the placing of overhead lighting units and the finish of the machines to avoid as far as possible risk of glare.

DRAWING OFFICES

83. In drawing offices the main requirement is high uniform brightness on the drawing boards in order to resolve fine detail, the elimination of hard shadows from the working edges of tee squares and set squares, and the avoidance of localized reflections from white paper and glazed tracing linen which cause discomfort glare.

The design of the installation will depend somewhat on the type of drawing board adopted. In offices for architectural staff, for instance, the traditional horizontal drawing board is invariably used, but in engineering offices the vertical-type drawing board and drafting machine is usually preferred. Adjustable vertical-type boards have the merit that they can be tilted to avoid specular reflection of the overhead light sources from glossy paper, or tracing linen, and that shadows from straight edges fall beneath them where they do not interfere with the work. With fixed horizontal boards, on the other hand, there is more risk of reflected glare and awkward shadows from overhead units of high brightness. Local lights are often preferred by draughtsmen because of the control of the direction of the light and the high illumination possible for fine work. The practice of using lamps close to the paper, however, results in patches of high brightness which can be a source of distraction to other workers, and there appears to be no reason why general lighting installations, if well designed, should not give satisfaction.

We recommend that a minimum illumination of 30 lm./sq. ft. be provided on the boards with the units arranged so that the light mainly comes from the left front of the draughtsman.

TRACING OFFICES

84. We have already noted that tracing represents a particularly difficult task owing to the reduction of visibility in the work by tracing papers and linen and the risk of specular reflection from glazed linen and glossy pencil lines. We recommend a minimum illumination of 30 lm./sq. ft. and preferably an illumination not below 50 lm./sq. ft. where the work is very fine and protracted and may be unfamiliar to the tracer, such as often obtains in offices devoted solely to tracing. In such circumstances, supplementary local lights, designed to minimize the risk of glare to other workers, may be justified in order to achieve the high brightness and contrast required.

For detailed continuous work we think there is much to recommend self-illuminated tracing tables as it is then easy to obtain a high brightness through the paper and to increase the apparent contrast of the original drawing. For comfortable working, the brightness of the illuminated glass plus drawing and tracing will depend upon the general room illumination and should not be more than about five times the general surround brightness. It is advisable also to screen temporarily the parts of the glass table not covered by the drawing to minimize the risk of glare.

FILING ROOMS

85. In rooms where active filing is done as distinct from places where files are stored, a minimum illumination of 20 lm./sq. ft. is needed at the place where the process of filing and sorting papers is carried out. The same level of illumination should be provided on the vertical plane where files are stored vertically and have to be frequently consulted *in situ* and also on the card surfaces of card index systems. We have noticed some filing systems which employ cards with shiny surfaces. In general we are of opinion that these create difficulties which might well be avoided.

CONFERENCE AND BOARD ROOMS

86. Many conference rooms are used both for general discussions and for the examination of documents with fine detail such as small-scale prints of drawings. An illumination of the order of 10 lm./sq. ft. is recommended.

RECEPTION ROOMS, INQUIRY OFFICES, CRUSH AND ENTRANCE HALLS

87. The illumination of entrance halls and reception areas should be designed to avoid both gloomy and garish effects, and unless the hall is used by staff for sustained clerical work a moderate amount of discomfort glare is permissible in order to achieve an effect of brightness and sparkle. For large offices brightly illuminated entrance halls have a definite prestige value. A general illumination of not less than 6 lm./sq. ft. at floor level, with supplementary lighting on the reception desks, is recommended.

CORRIDORS

88. A high level of illumination is not essential in corridors and a minimum illumination of 1 lm./sq. ft. at floor level would normally be adequate. The distribution should be such that dark corners and sudden changes in general brightness are avoided.

STAIRS

89. Lights for stairs should be placed at frequent intervals, according to the type of stair, to avoid noticeable changes in the illumination, and should be arranged so that each tread throws a shadow covering between 25 per cent and 75 per cent of the width of the tread beneath.

The ceilings and upper parts of walls should be decorated in light colours, and it is an advantage if the nosing of each step can be in a lighter material than the tread. The lighting units should be well shielded from view or be of low surface brightness to avoid glare to people ascending or descending the stairs. A minimum illumination of 1 lm./sq. ft. at the level of each tread is recommended.

LAVATORIES AND W.C.S

90. A well-diffused light of a minimum intensity of 3 lm./sq. ft. is desirable in lavatories both for the convenience of users and to encourage proper cleaning and maintenance. Separate lighting units are advisable in each W.C. compartment, under individual control, or operated by the door mechanism.

WIRING AND SUPPLY PIPE INSTALLATIONS

91. Our colleagues of the Electrical Installations Committee, in their Report, published as No. 11 of the *Post-War Building Studies* (19), have given information and guidance on the best practice for electrical wiring installations in various buildings including offices. Therefore we do not propose to give detailed information about wiring layout, but only to emphasize one or two matters, such as the disposition of lighting outlets, which directly affect our work. For all matters relating to the control, fabrication, and detailed arrangements of the installations, reference should be made to the Report of the Electrical Installations Committee, to the Institution of Electrical Engineers' Regulations for the Electrical Equipment of Buildings, and the appropriate Codes of Practice. Similarly, where gas lighting is installed, reference should be made to the recommendations of the Gas Installations Committee in their Report published as No. 6 of the *Post-War Building Studies* (20). The following comments about electric wiring would in general apply also to the layout of gas supply points.

92. For wiring layouts in modern office spaces there are two possibilities:

1. To design the installation from the beginning as a fixed arrangement, closely related to the building frame, and capable of giving uniform illumination over the whole of the floor space.

2. To bring the rising conductors in sufficient capacity to each floor level to feed tenants' meter positions, leaving the layout of the wiring and the position of outlets to be determined by the tenants themselves.

In view of the desirability of providing a good illumination over the whole of the usable office floor space—more or less irrespective of desk positions—and the possibility of using artificial light as a supplement to daylight, the first method is recommended for new buildings. In practice, the floor construction is commonly divided into bays or panels about the size of a single office unit 10–13 ft. wide, and a very usual and satisfactory arrangement is to provide two or three ceiling outlets for each bay according to the depth of the office. This spacing also works out reasonably well when a number of office units are merged to form a large general office. Any local extensions to the wiring can usually be carried out satisfactorily and unobtrusively.

We are informed by expert witnesses that in London, where offices are let and re-let to different tenants, the second method is customary, the main advantage being that tenants are free to put in the type of installation which suits their individual needs. We are of opinion, however, that this may involve an unnecessary waste of labour and materials in stripping and reinstating the wiring, with probably a low standard of workmanship and an untidy appearance through the use of surface wiring. We therefore recommend that the first method be adopted unless there is good reason to the contrary.

93. In view of the likelihood of changes in the use of office work spaces and the possibility of higher standards of illumination we consider it advisable to design the wiring so that the present recommended levels of illumination can be achieved by incandescent tungsten lamps. Wiring designed on this basis has the merit that future increases in the levels of illumination, required because of improved standards or changes in office organization, can probably be met by the use of more efficient light sources. There is also the point that if standards are advanced beyond the present recommended levels, the use of tungsten lamps alone may be considered objectionable from other points of view, as for instance, heat radiation.

94. As some of the more difficult kinds of office work may best be served by supplementary local lights we also recommend that adequate provision be made for lighting supply outlets at low level.

95. For general economy and particularly when the artificial lighting is intended to supplement daylight, switching should be arranged so that the lighting to those parts of rooms furthest from the windows can be brought independently into operation.

PART IV. IMPROVEMENTS TO THE DAYLIGHTING OF EXISTING BUILDINGS

96. The Survey showed that natural and artificial lighting is poor in many existing offices. Our conclusions about artificial lighting apply equally to old and new buildings, but some explicit suggestions for dealing with poorly daylighted buildings may help owners and managers to improve them. Assuming nothing can be done about external obstructions, it is merely a question of various expedients, of which the following are most useful:

Minor alterations to the structure in order to increase the effectiveness of existing windows.

The use of external reflectors.

Diffusing glasses to redirect the available light into parts of the room where it is most wanted.

Paint treatments.

Rearrangement of the furniture.

Supplementary light from artificial sources.

97. Where it is practicable to increase the size of existing windows this can give valuable help. As a general rule, where external obstructions are present, most advantage will result from raising existing window heads as high as possible.

Minor alterations which suggest themselves are the removal of windows with frames, mullions, transoms and bars which are unnecessarily large in cross sections and their replacement by windows designed to offer the minimum of obstruction.

98. External reflectors are used to direct light into inadequately lit city offices. Well designed and placed they can improve the general illumination, but they need to be kept in good condition to retain their effectiveness. Generally they spoil the external appearance of buildings never intended for such expedients.

99. Diffusing and redirecting glasses are other expedients but they require to be used skilfully if they are to be successful. Prismatic glass, which is classed as a redirecting glass, is the most obvious type to use and can be successful in redirecting light from a high angle so that it enters the room at a low angle. For vertical glazing it must, however, be placed at the face of the building and not set in under the lintel if it is to receive the light it is intended to redirect. A disadvantage with the glass is the collection of dirt on the ribs which are not easy to clean.

Diffusing glasses diffuse the light which they receive and do not redirect it at any particular angle. They become bright when light falls upon them and their bright surface can then light the interior. Their brightness depends upon the amount of light they receive, and therefore like the prismatic glasses they must be well placed to receive light from the sky.

Redirecting and diffusing glasses have lower transmission factors than clear glass and the total efficiency of any window is therefore reduced by their use. They are likely to be worth while only if the amount of light sent to otherwise dark parts of rooms is adequate for office work, and this is seldom likely to occur except on very bright sunny days. Certainly they are less likely to give good working conditions than good artificial light. Often the illumination in the rooms where they are installed is still so poor that their surface brightness is glaring in contrast with the low brightness of their immediate surroundings.

It should be appreciated that there are some circumstances in which these special glasses serve a useful purpose. Many are intended to let in light without permitting a view of the interior. Some are used for light fittings, others for diffusing sunlight, and some for decorative purposes. Our remarks relate only to their use as a means for improving daylight in existing buildings.

100. The fourth method of improvement is by skilful decoration. We have already pointed out the value of light and colourful interiors and now emphasize that they can do an immense amount to give an air of freshness and cheerfulness to older buildings (see Figs. 20–25). Often it is found that the gradual modernization of the lighting has in a sense left the decorations behind, insofar as dark colours and stained woods, which once did not seem too dark, now in fact offer too great a contrast with the stronger light sources.

101. Some improvements to the lighting of individual desks can often be attained by rearrangement of the furniture. In offices with high windows, giving high angle views of large areas of sky, the visual comfort of staff sitting near the windows can also be improved by placing their desks at an angle with the window so that direct views of bright sky are avoided.

102. Finally, the most advantageous course is to use artificial lighting to supplement the inadequate daylight. In Part II we have described ways of extending the useful zone of office work by the use of carefully designed artificial light sources. This is also a useful and practicable method of improving the illumination of poorly daylighted existing offices and a far more certain and comfortable expedient than the use of external reflectors and other devices.

PART V. LEGISLATIVE ASPECTS

103. At present no by-laws govern either the fenestration of office buildings, or the provisions for artificial lighting, for the express purpose of ensuring reasonable illumination for office work. For instance, By-law 39 of the by-laws made under the London Building Act (Amendment) Act 1935 (13) requires the elevational area of windows above the ground floor to total not more than 50 per cent of the total elevational area above the ground floor, but this is essentially a fire precaution and is not a serious constraint so far as lighting is concerned. There are common regulations also which govern the height of buildings and these are intended, partly, to limit obstructions to daylight. Similarly, the Model By-laws of the Ministry of Health stipulate the maximum amount of open space about buildings in relation to their height (clauses 80–87) and the minimum total amount of window area in habitable rooms (clause 88 [1]). None of these, however, directly deal with office lighting.

Three questions arise.

104. Firstly: should there be regulations to ensure good natural light in offices?

We look forward to the modification of by-laws governing the restrictions of building height along the lines described in Part II of this Report. Also we have noticed with interest recent references to possible measures in the Report of a Committee of Enquiry into Health, Welfare, and Safety in Non-Industrial Employment (14) (The Gowers Committee). There it is recommended that Section 5 (4) of the Factories Act of 1937 should be extended to offices, and this would require occupiers to keep windows clean and free from obstruction. This is one of a number of recommendations made to extend factory and shop legislation to offices, and although alone it is not a vital element, it should strengthen the general attitude to good daylighting and so we offer the recommendation our support. At the same time it is our view that much can be done by Local Authorities and planning officers, when examining designs for office blocks submitted to them, to ensure that the standards referred to here and in other Reports (1) (2) are maintained as far as possible.

105. Secondly: should there be regulations for artificial lighting in offices?

Minimum standards for artificial lighting are laid down for factories and schools, the former in regulations made under Section 5 (2) of the Factories Act of 1937 and the latter under the Regulations resulting from the Education Act of 1944. There is also a general provision for shop lighting in the Shops Act of 1934. Again in the Gowers Committee Report the recommendation is made that the relevant part of the Shops Act, Section 10 (3), be applied to offices. By this move occupiers would be required to supply "suitable and sufficient lighting." The imposition of exact minimum standards with all the difficulties of definition and application was considered premature, and it was thought that the proper course would be to lay down a general requirement in this way and then to leave the matter for the time being to the enforcement authority's inspectorate. We comment on the views of the Gowers Committee to the extent of saying that we are in full accord. The results of our inquiry show how great is the need for some action.

106. Thirdly: should changes be introduced in the law relating to rights of light?

This is a matter of long standing and great complexity into which we do not feel we should enter. Nevertheless, the present state of affairs is criticized and may therefore be having undesirable effects. It seems to us that the whole subject of prescriptive rights to light should be investigated by the appropriate authorities, bearing in mind that it would seem desirable that the right to sufficient light should be a public right and not a private privilege.

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APPENDIX I

A SURVEY OF LIGHTING IN OFFICES

The Inquiry by the Social Survey Division of the Central Office of Information, the results of which are reproduced in this Appendix, was carried out at our request to ascertain the state of office lighting at the present time. Although there is much information which has only an indirect interest for us at the moment, we include it for record purposes and further study. Some of the findings which more directly affect our work have already been mentioned in our Report, but for the convenience of readers we preface the Inquiry with our own summary of a few of the more important matters of general interest.

SUMMARY

DAYLIGHTING

7 per cent of office staff work in rooms without windows though the majority of these have skylights or glass screens.

16 per cent of office staff work in rooms where the glass area is less than 10 per cent of the floor area. A minimum ratio of 1 : 10 is a requirement of most by-laws and regulations.

21 per cent of office staff receive no direct daylight on their work.

These data were taken on a national sample. It is therefore likely that in the dense central areas of cities the conditions would be considerably worse than the figures suggest. The figures are bad enough, however, for they show that at least one person in five works in insufficient daylight. People are often said to be surprisingly insensitive to their working conditions, but 20 per cent confirmed that they felt they could see only badly or not at all by daylight alone. Complaints were about quantity rather than quality.

SUNLIGHTING

Nearly three persons in five have some sunshine in their offices in winter, and this rises to about three out of four in summer. It is known that valuers and lessees do not attach much importance to well-sunlighted offices, but office staffs do. 84 per cent of all informants said they liked to have sunlight at some part of the day, though naturally protective measures against excess in summer were generally thought desirable. The nearly unanimous desire of office staff for good sunlighting is a factor for architects and town planners to take into account, even if valuers prefer to ignore it. In the course of time, rising standards may persuade the last named to value it.

ARTIFICIAL LIGHTING

Three people out of four had incandescent electric lighting only, one in five had fluorescent, and the remainder had a mixture of the two.

Two-thirds of the installations gave direct light downward only, over a quarter gave general lighting, and 4 per cent gave indirect lighting.

Over one-third of the sample controlled their own light independently of the main lighting.

Intensities of light for particular kinds of work were noted as follows.

DRAWING OFFICES

3 per cent had less than 10 lm./sq. ft.; the mode of readings was 32·5 lm./sq. ft. Our recommended level is 30–50 lm./sq. ft.

TYPING

Nearly 30 per cent had less than 10 lm./sq. ft.; the mode of readings was 10·9 lm./sq. ft. Our recommended level is 20 lm./sq. ft.

COMPUTING, ETC.

Over 30 per cent had less than 10 lm./sq. ft., and the mode of readings was 11·7 lm./sq. ft. Our recommended level is 20 lm./sq. ft. as a minimum.

LEDGER

Over 35 per cent had less than 10 lm./sq. ft., and the mode was 9·0 lm./sq. ft. We recommend 20 lm./sq. ft.

CLERICAL

Nearly one-half had less than 10 lm./sq. ft., and the mode of readings was 8·0 lm./sq. ft. We recommend 15–20 lm./sq. ft. according to whether the work is sustained or intermittent.

In sum, intensities in drawing offices seem reasonably close to our recommendations. From a third to a half of all other types of work, however, are done in materially less light than we recommend, the highest proportion and the lowest illumination being for ordinary clerical work. It is evident that some slight attention is given to work which is visually more difficult like typing and computing, but it is very inadequate. Computing, in particular, seems to be badly served if the points made in our Report are referred to.

Artificial light is used for over a third of the time in winter, though some of it is merely for the benefit of the people farthest from the windows. 16 per cent said they never have to use artificial light by day, even in winter, but 22 per cent have it on all the time.

If the figures for people who said they saw "fairly well" and "well" are read together, there is apparently more satisfaction with artificial than with natural lighting; but there is an indication in the data that a lower standard of satisfaction is the criterion in artificial lighting. However, among those who said they saw well or fairly well, there are many more criticisms of the artificial lighting than of the daylighting—criticisms which focused upon quality rather than the amount of light.

A SURVEY OF LIGHTING IN OFFICES

By P. G. Gray and T. Corlett

An Inquiry carried out by the Social Survey Division of the Central Office of Information in February 1948

PURPOSE

1. The object of the Survey was to obtain information about the general state of natural and artificial lighting in offices in Great Britain with regard both to the facilities available and to the workers' opinions of these facilities.

METHOD

2. The initial difficulty was how to obtain a representative sample of office workers at their places of work. No complete list of offices existed from which a random sample could be selected and insufficient information was available about the distribution of workers among different types and sizes of offices to enable quotas of office staff to be set for investigators. The following method was therefore adopted.

During a series of monthly surveys in connection with another inquiry in which the persons to be interviewed were selected at random from the Maintenance Registers and were representative of the civilian adult population of Great Britain, all clerical workers were asked to state the address of their place of work, the object of this question being explained to them. Investigators then called at these offices with instructions to interview four workers (where possible) in each office. After the co-operation of the management had been secured, the names of the four workers to be interviewed were selected at a constant interval from a list (time-sheet, etc.) where this was available. In some small offices the manager or the investigator wrote out a list of the employees for this purpose.

As the basis of this method was a random sample of office workers, it could be expected to provide the correct number of workers in offices of different sizes, thus overcoming the difficulty mentioned above.

A copy of the questionnaire used for the interviews and the instructions to investigators is shown at the end of this Appendix. The questions are roughly divided into three classes: (i) certain general classification data relating to each informant and to the office in which he was employed; (ii) questions asked of the informant about his opinions on the natural and artificial lighting of his work; and (iii), measurements and other observations made by the investigator.

THE SAMPLE

3. Interviews were obtained with 1408 office-workers in 358 offices throughout Great Britain. 13 per cent of these offices (accounting for 13 per cent of the total of interviews) were "substitutes" visited by an investigator when she had been unable to obtain access to an original office on her list. Investigators were instructed to use as substitutes offices of a similar size and industrial group to the original. A list of the towns in which interviews took place is given on page 65.

Tables 1, 2, 3, and 4 give the distribution of the sample of office workers by Civil Defence Region, by sex, by age, and by industry-group. Where significant differences are present the distributions of the present sample are compared with data relating to random samples of clerical workers obtained at about the same time.

TABLE 1. REGIONAL DISTRIBUTION OF SAMPLE

REGION	THE SAMPLE %
Scotland	5
North	5
North-East	9
North-West	14
North Midlands	5
Midlands	13
East	6
London	25
South	4
South-West	6
Wales	4
South-East	4
	100
Total number of office workers in sample	1408

The regional distribution of the sample did not differ significantly from that of the sample of clerical workers mentioned previously.

TABLE 2. SEX DISTRIBUTION

SEX	LIGHTING SAMPLE %	SAMPLE OF CLERICAL WORKERS %
Male	42	47
Female	58	53
	100	100
Number in sample	1408	1755

TABLE 3. AGE DISTRIBUTION

AGE	LIGHTING SAMPLE			SAMPLE OF CLERICAL WORKERS		
	MALE %	FEMALE %	ALL %	MALE %	FEMALE %	ALL %
Up to 29	26	64	48	29	64	47
30 to 39	31	20	25	23	17	20
40 to 49	26	11	17	23	12	17
50 and over	17	5	10	25	7	16
	100	100	100	100	100	100
Number in sample	588	820	1408	823	932	1755

Tables 2 and 3 suggest that male staff were slightly under-represented in the sample, while males aged 30-39 were over-represented at the expense of males aged 50 and over. The net result of this is that office-workers aged 50 and over are slightly under-represented in the sample as a whole. The bias is not likely to be serious.

TABLE 4. INDUSTRIAL DISTRIBUTION

INDUSTRY IN WHICH INFORMANT IS EMPLOYED	LIGHTING SAMPLE %	SAMPLE OF CLERICAL WORKERS %
National and Local Government	26	24
Manufacturing	34	23
Others	40	53
	100	100
Number in sample	1408	851

Workers in manufacturing and in other industries were somewhat over- and under-represented respectively in the sample, while the proportion in National and Local Government concerns was correct. However, it will be seen, from data given in the body of this Report, that the only marked difference observed between offices of manufacturing industries and those of "other industries" is in respect of size, *i.e.* the number of office workers employed. (See Table 6.)

The effect of applying the industrial distribution of the clerical workers' sample (Table 4) to the size distributions for each industry-group in the present sample (Table 6) to give a re-weighted size distribution for "all industries" suggests that the proportion of office workers who work in offices where under 20 staff are employed should be about 36 per cent, whereas the proportion in the sample was 32 per cent. This is not a serious difference.

TIMES AT WHICH INTERVIEWS WERE MADE

4. It was important that interviews should be made at times when a reasonably high proportion of office workers could be expected to be using artificial light, for measurements of the intensity of artificial light were to be made. Investigators were therefore instructed to make their calls during afternoons only. The times at which interviews were made are summarized below.

TABLE 5. TIMES AT WHICH INTERVIEWS WERE MADE

TIMES OF INTERVIEW	%
Up to 3 p.m.	38
From 3 p.m. to 4 p.m.	40
From 4 p.m. to 5 p.m.	19
After 5 p.m.	3
	100
Number of interviews	1408

PART II—A DESCRIPTION OF THE OFFICES

It is important to note that the base of all percentages given in the tables of this section and throughout the Report is the total number of office workers in the sample to whom the data refer. In no case is the base a number of offices.

SIZE OF OFFICES: NUMBERS OF OFFICE WORKERS EMPLOYED

5. Investigators recorded for each informant the total number of office workers employed by the particular organisation or its branch, at the address given.

TABLE 6. SIZE OF ROOMS

NUMBER OF OFFICE WORKERS EMPLOYED	ALL INDUSTRIES	INDUSTRY		
		NATIONAL AND LOCAL GOVT.	MANUFACTURING	OTHERS
	%	%	%	%
Up to 5	11	2	6	21
6–10	9	6	9	11
11–20	12	7	10	18
21–50	16	20	16	14
Over 50	52	65	59	36
	100	100	100	100
Number in sample	1408	373	479	556

It will be seen that whereas 15 per cent of office staff in National and Local Government offices worked in rooms employing up to 20 office staff, the proportion in manufacturing industries was 25 per cent and in "other industries" 50 per cent.

NUMBERS OF STAFF IN ROOMS

6. The number of office workers who normally worked in the room where each informant was working was recorded.

TABLE 7. NUMBER OF WORKERS IN ROOM

NUMBER OF WORKERS IN ROOM	ALL INDUSTRIES %	INDUSTRY: NATIONAL AND LOCAL GOVT. %	MANUFACTURING %	OTHERS %
1	9	9	7	10
2–4	35	37	30	38
5–10	26	30	27	24
11–20	14	12	16	11
21–50	10	9	14	10
Over 50	6	3	6	7
	100	100	100	100
Number in sample	1408	373	479	556

The proportion of National and Local Government staff working in rooms containing over 20 workers was 12 per cent, while the proportions for manufacturing industries and other industries were 20 per cent and 17 per cent respectively. This is probably a reflection of the wider use of "open offices" among commercial organisations than in National and Local Government concerns.

ROOM AREA PER PERSON

7. Certain simple measurements made by investigators enabled the ratios given in the following Table to be calculated.

TABLE 8. ROOM AREA PER PERSON

SQUARE FEET OF ROOM AREA PER PERSON	ALL INDUSTRIES %	INDUSTRY: NATIONAL AND LOCAL GOVT. %	MANUFACTURING %	OTHERS %
Up to 40 sq. ft.	16	8	17	20
41– 60 ,,	27	23	31	26
61– 80 ,,	19	25	17	19
81–100 ,,	14	16	15	11
Over 100 ,,	24	28	20	24
	100	100	100	100
Number in sample	1408	373	479	556

It will be seen that National and Local Government employees enjoy more space than the rest. There were no marked differences between the conditions in manufacturing industries and in "other industries."

It is interesting to compare these observed conditions with the standards which are generally considered desirable. In the Report, *Working Conditions in the Civil Service*,[1] prepared by a Study Group appointed by H.M. Treasury, it is stated

[1] Her Majesty's Stationery Office, 1947, price 4s. net.

(p. 24) that 40 sq. ft. of floor space per person should be a bare minimum for typists, with about 60 sq. ft. for others. By these standards about 15 per cent of office workers were working in "overcrowded" conditions.

TYPES OF WORK

8. Table 9 shows a classification of the "main" work done by informants.

TABLE 9. TYPES OF OFFICE WORK DONE

TYPE OF WORK	%
General clerical	52
Typing	22
Ledger	9
Operating machine	7
Drawing	5
Filing	2
Other types	3
	100
Number in sample	1408

HOURS OF WORK

9. The times of beginning and ending work on a normal working day at that time of the year (February-March) were asked of all informants.

TABLE 10. TIMES OF BEGINNING AND ENDING WORK

BEGIN WORK AT (A.M.)	%	FINISH WORK AT (P.M.)	%
8.15 or earlier	4	4.30 or earlier	3
8.30	20	4.45	2
8.45	9	5.00	29
9.00	56	5.15	8
9.15	2	5.30	42
9.30	6	5.45	3
9.45 or later	3	6.00 or later	13
	100		100
Number in sample	1408		1408

SPECTACLES

10. 47 per cent of informants wore glasses for work. The percentages for each age-group are given in Table 11. Briefly, 51 per cent of males compared with 45 per cent of females were found to wear glasses, but this difference is probably due to the fact that the average age of the men was higher than that of the women. There were no significant differences between the proportions of men and of women of a given age-group who wore glasses.

TABLE 11. PROPORTIONS OF OFFICE WORKERS IN EACH AGE-GROUP WEARING GLASSES FOR WORK

AGE (YEARS)	DOES THE INFORMANT WEAR GLASSES FOR WORK?			
	YES %	NO %	SAMPLE %	SAMPLE NOS.
Up to 29	34	66	100	680
30–39	49	51	100	348
40–49	57	43	100	241
50 and over	90	10	100	139
All ages	47	53	100	1408

PART III—NATURAL LIGHTING

WINDOWS

11. Investigators were instructed to note a window only if it was vertical and communicated with the outside. Glazed partitions to corridors, for example, were not counted as windows.

7 per cent of informants were working in rooms without windows, but some of these had skylights and some received daylight through glass screens. In 2 per cent of cases no daylight could enter the room.

TABLE 12. NUMBER OF WINDOWS IN ROOM

NUMBER OF WINDOWS IN ROOM	%
No windows	7
One	27
Two	21
Three	11
4–6	18
7–9	7
10 or more	9
	100
Number in sample	1408

TABLE 13. ORIENTATION OF WINDOWS

NUMBER OF DIRECTIONS IN WHICH WINDOWS FACE	%
One direction	63
Two directions	26
Three directions	10
Four directions	1
	100
Number in sample (those with windows)	1311

15 per cent of all informants had skylights.

For those with windows certain simple measurements made by the investigators enabled the ratios in Table 14 to be calculated. (See Questions 31–37, page 62.) Investigators were not required to make any calculations themselves.

Table 14. Ratio of Window Area to Room Area

TOTAL WINDOW AREA / ROOM AREA	ALL INDUSTRIES %	INDUSTRY: NATIONAL AND LOCAL GOVT. %	MANUFACTURING %	OTHERS %
Up to ·1	16	13	18	15
Over ·1 to ·2	45	48	43	44
Over ·2 to ·3	24	24	24	25
Over ·3 to ·4	8	9	7	8
Over ·4 to ·5	4	3	5	3
Over ·5	3	3	3	5
	100	100	100	100
Number in sample (those with windows)	1311	368	431	512

About 15 per cent of the workers are working in offices which do not comply with the Model By-laws of the Ministry of Health.[1]

This table shows no significant differences between industries.

Certain data were recorded which refer to the window nearest in a horizontal direction to the person concerned.

Table 15. Area of nearest Window

AREA OF WINDOW NEAREST TO WORKER	%
Up to 10 sq. ft.	5
11–20 ,,	28
21–30 ,,	27
31–40 ,,	14
41–50 ,,	8
51 sq. ft. and over	18
	100
Number in sample (those with windows)	1311

Table 16. Working position in relation to nearest Window

POSITION OF WORKER	%
Facing nearest window	20
Sideways to nearest window	66
Back to nearest window	14
	100
Number in sample (those with windows)	1311

There were 563 workers with windows facing in one direction only and who sat sideways to the nearest window. Of these, 48 per cent had the nearest window on their right side and 52 per cent on their left side, a difference which is not statistically significant.

The following data relate to the nearest window as seen from the informant's working position. If the nearest window could not be seen without turning the head more than 90° it was described as "not visible."

[1] See page 44, para. 12.

Table 17. Transparency of nearest Window

COMPOSITION OF WINDOW	%
All clear glass	61
Partly clear glass	20
No clear glass	6
Nearest window not visible	13
	100
Number in sample (those with windows)	1311

Table 18. View through nearest Window

NATURE OF VIEW THROUGH WINDOW	%
Long view	24
Short view	49
No view	27
	100
Number in sample (those with windows)	1311

The view was recorded as "short" if it was across a street or less; otherwise "long." Evidently 73 per cent of workers with windows (68 per cent of the whole sample) had some kind of a view through their nearest window. About a third of these displayed regular movement such as people passing and traffic. Informants were asked if they considered their view to be pleasant or not pleasant.

Table 19. Nature of View through nearest Window—Workers' Opinions

INFORMANT'S OPINION OF VIEW	INFORMANTS WITH A VIEW %	INFORMANTS WITH WINDOWS %	ALL INFORMANTS %
Pleasant	41	30	28
Not pleasant	56	41	38
Neutral	3	2	2
No view	—	27	32*
	100	100	100
Number in samples	962	1311	1408

* This includes the 7 per cent of the sample who had no windows.

WALLS

12. Investigators were asked to grade the upper portion of the office walls into three categories, light, medium, or dark, by placing two pieces of cardboard, similar in reflectivity to the key shown in Fig. 5, against the wall surface. Walls that appeared lighter than A (reflection factor 50 per cent) were counted as "light," walls that appeared darker than B (reflection factor 20 per cent) were counted as "dark."

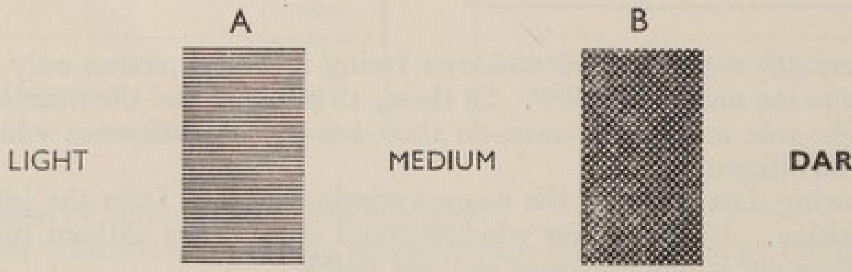


Fig. 5. REFLECTIVITY OF WALLS

TYPICAL EXAMPLES OF OFFICE BUILDINGS SHOWING DEVELOPMENT OF FENESTRATION

Above, left :
1864. 59–60 Mark Row, London. Designed by George Aitchison. The arcading is typical of many commercial buildings of this period.

Above, right :
1864. Offices of W. D. and H. O. Wills Ltd., Redcliffe Street, Bristol. By Foster and Wood.

Left :
1878. Dashwood House, London. Designed by Robert Marsh.

Below :
1917. Cunard Building, Liverpool. Architects : E. A. Willinck and P. C. Thickness.

Above, left :
1932. Daily Express Building, London. Architects : H. W. Ellis and Clarke, F.F.R.I.B.A.

Above, right :
1932. 51–54 Gracechurch Street, London. Architect : L. S. Sullivan, F.R.I.B.A.

Centre :
1937. Great Westminster House, London. Architects : T. P. Bennett and Son.

Right :
1950. Offices at Wallsend, Northumberland. Architects : Richard Shepherd and Partners.

Plate Two

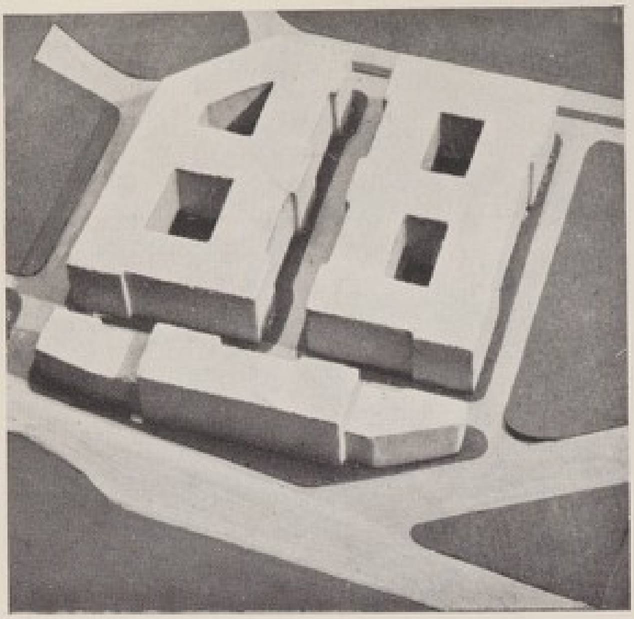
Left :
1950. Charles House, London. Architect : Arthur Ash, F.R.I.B.A.

Centre :
1949. The Prudential Building, Los Angeles, U.S.A. Architects : Wurdeman and Becket. Structural Engineer : Murray Erick.

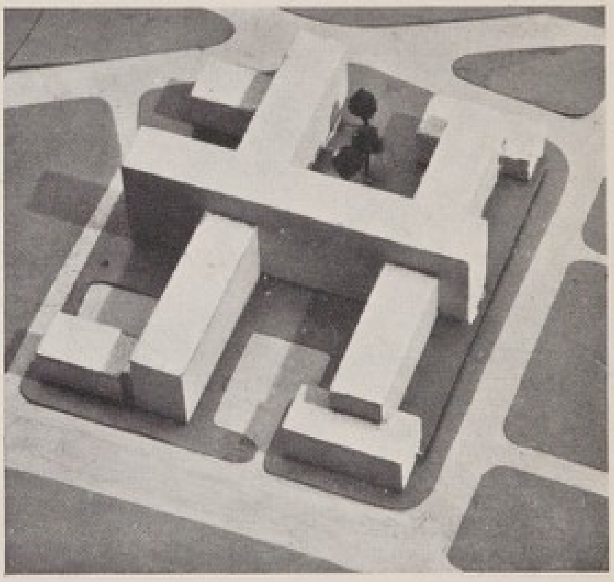
Below, left :
This Georgian window illustrates many of the desirable design features listed on page 14.

Below, right :
External reflectors, which are often used for inadequately daylighted city offices.

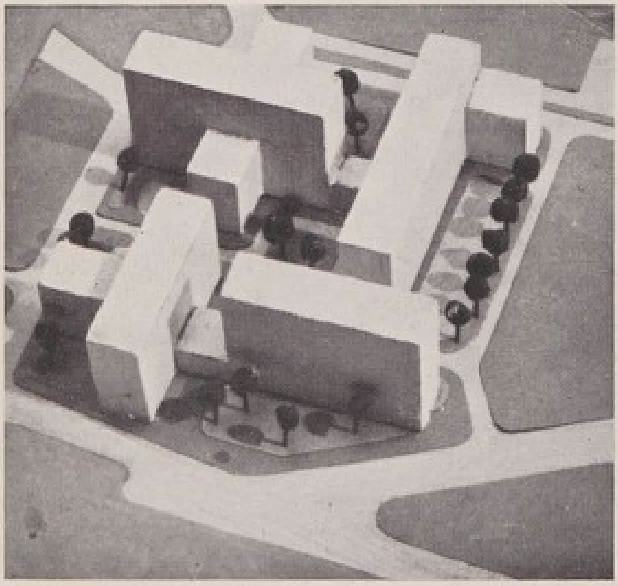
Plate Three



Typical traditional development of offices with internal light wells—described in the Report as corridor street development.



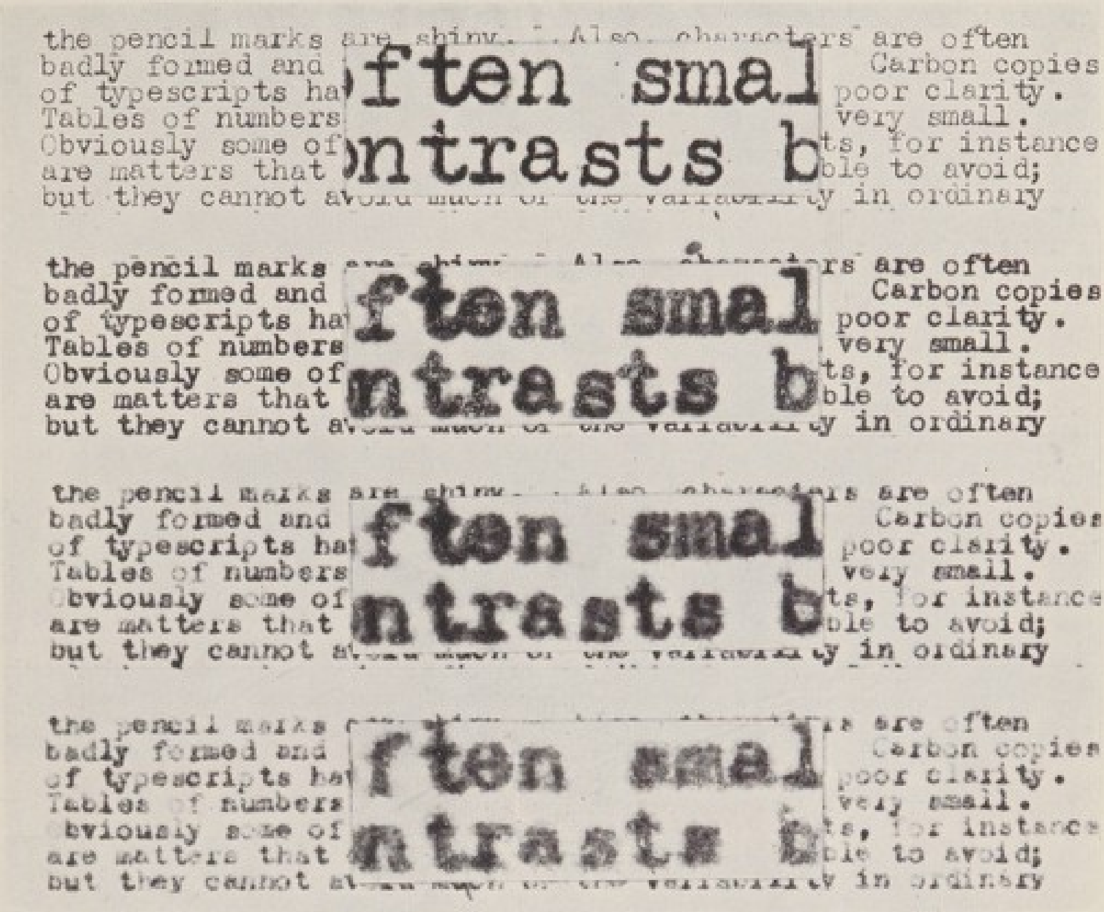
Development of a large site with open planning of the office blocks—a comb-shaped layout plan.



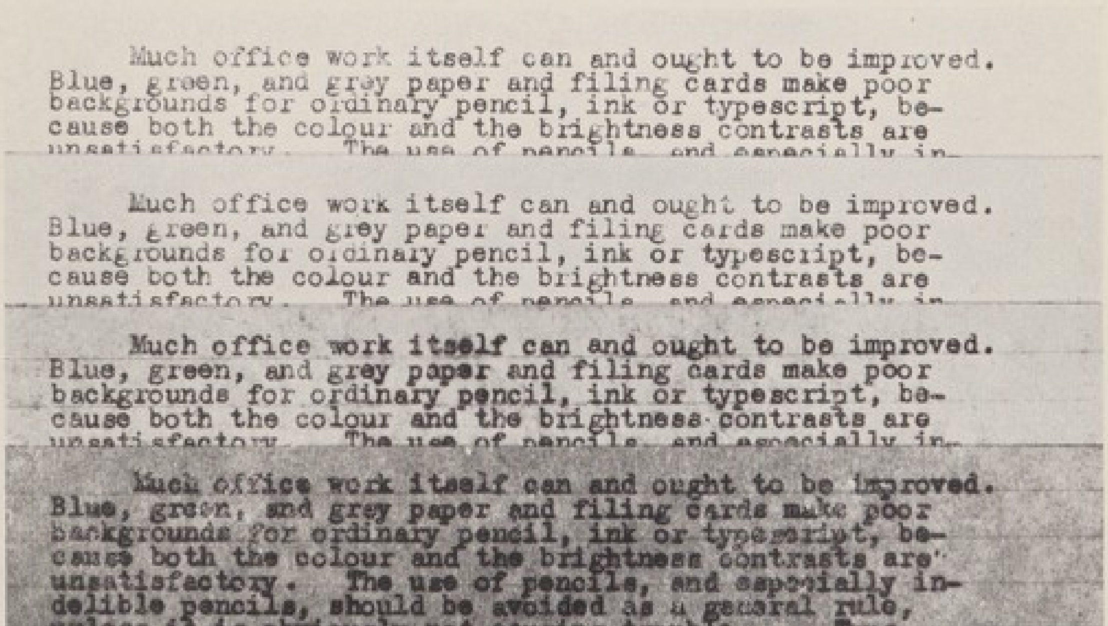
A similar site—a less formal arrangement.

Plate Four

TYPICAL EXAMPLES OF SOME FACTORS AFFECTING VISUAL SEVERITY OF OFFICE WORK

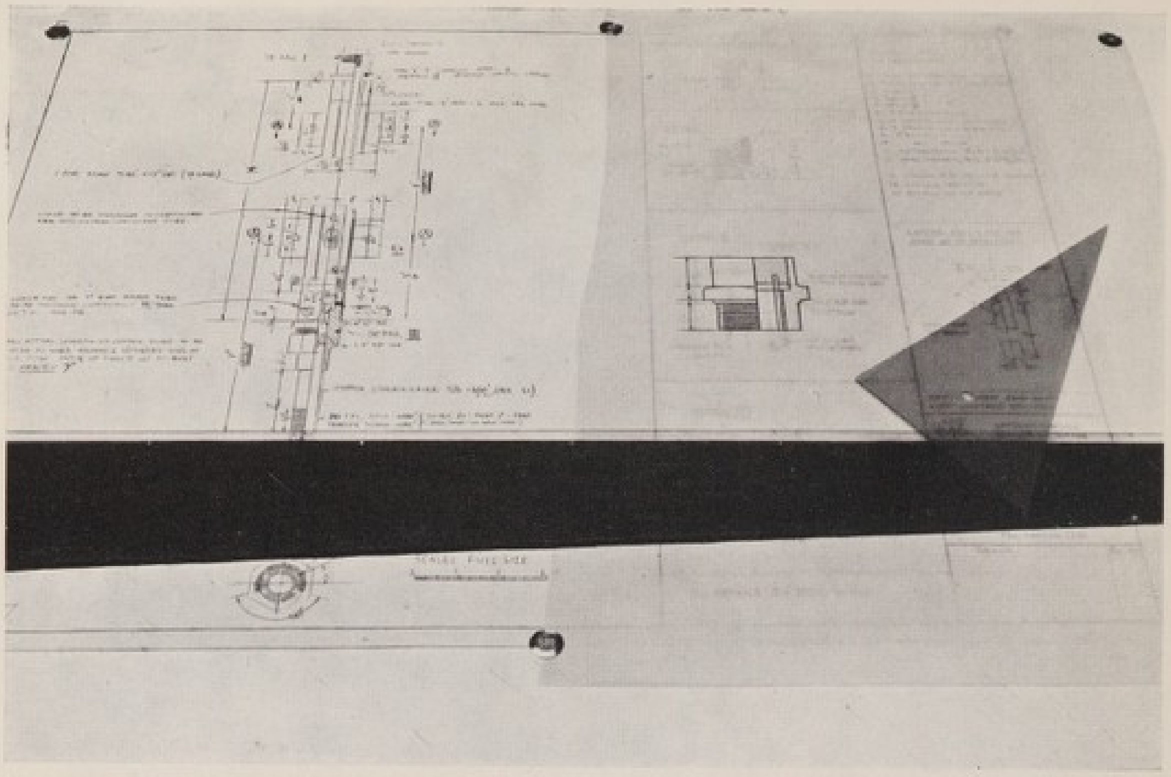


The progressive reduction in definition of carbon copies, with magnification to show the blurring of the letter outlines.

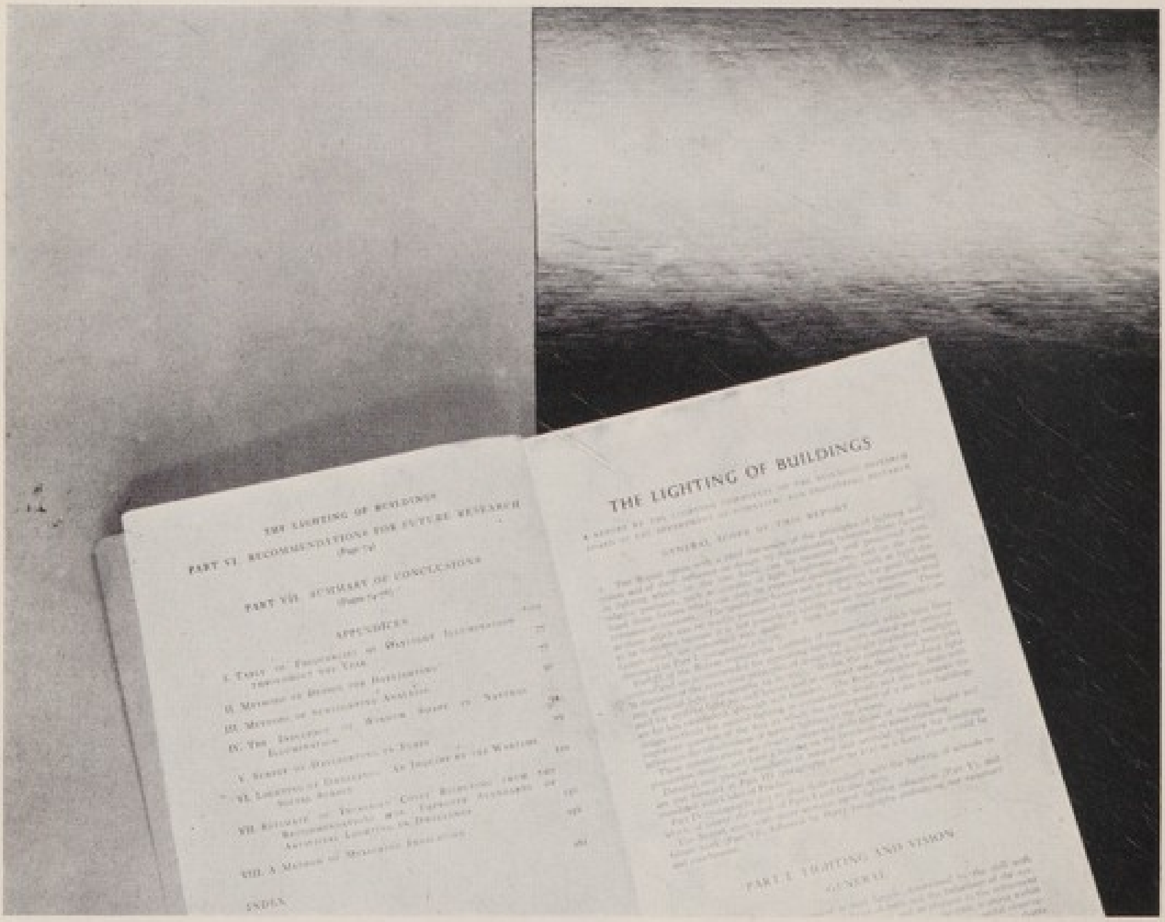


The loss of contrast between the background and the typescript, as a result of using cards and papers of unsuitable colours. In the fourth example the type would need to be much larger to compensate for the inadequate contrast.

Plate Five



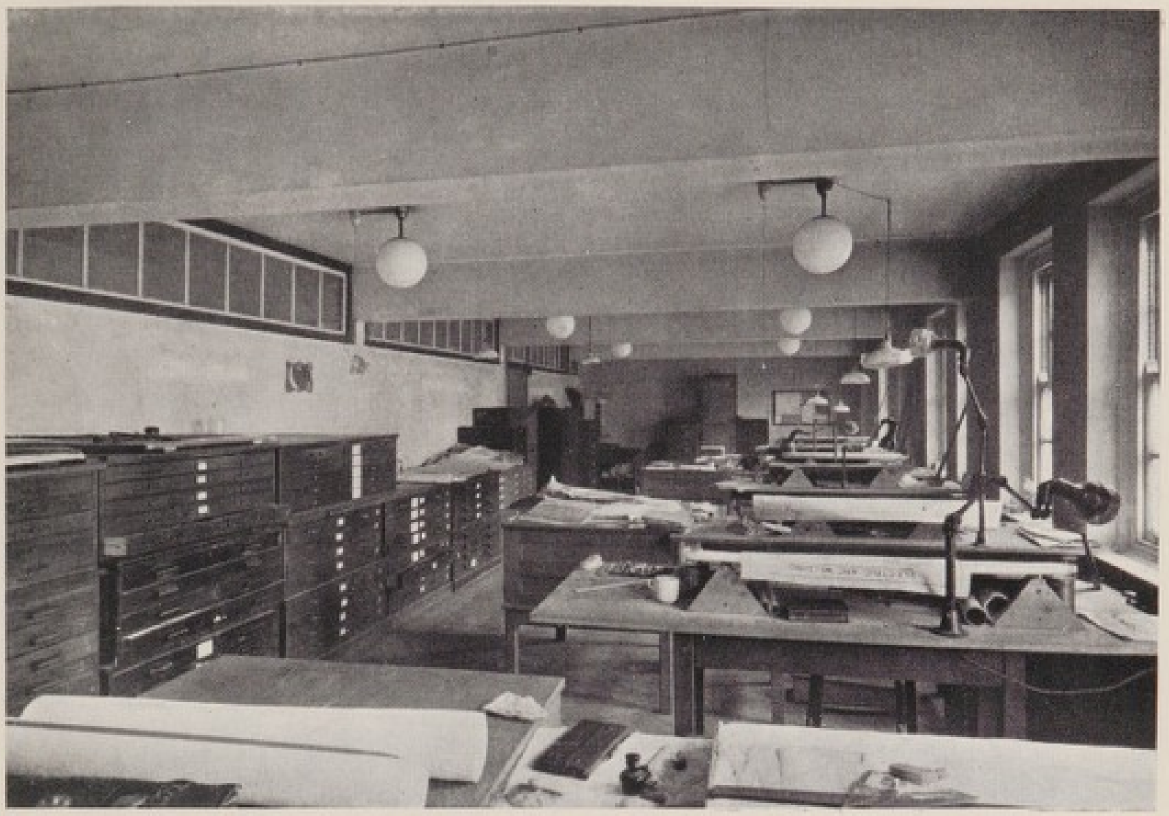
The serious reduction of visibility of faint lines on drawings by the imposed tracing cloth or paper is one reason why drawing office work is visually more severe than ordinary clerical work.



A satisfactory surface for a desk top—light colour, matt finish, contrasted with an unsuitable surface—dark colour, highly polished (see page 26).

Plate Six

IMPROVEMENTS TO EXISTING OFFICES



The drawing office, Ebury Bridge House, London, before redecoration.

The drawing office, Ebury Bridge House, London, after redecoration.

Plate Seven

The typing pool, Ebury Bridge House, London, before redecoration.

The typing pool, Ebury Bridge House, London, after redecoration.

The Table below shows the reflection factors of the walls of informants' offices.

TABLE 20

WALLS: LIGHT, MEDIUM, OR DARK	ALL INDUSTRIES	INDUSTRY		
		NATIONAL AND LOCAL GOVT.	MANUFACTURING	OTHERS
	%	%	%	%
Light	31	26	39	27
Medium	53	55	46	58
Dark	14	18	10	14
Glass screens	2	1	5	1
	100	100	100	100
Number in sample	1408	373	479	556

Office staff in the manufacturing industries apparently have the benefit of lighter decorations.

EFFECTIVENESS OF NATURAL LIGHTING

13. The essential question asked of all informants was: "Are you able to see well, fairly well or badly when working by daylight alone?" Earlier experience had indicated that these were reasonable divisions. A summary of the answers is given below.

TABLE 21. ABILITY TO SEE BY DAYLIGHT ALONE

ABILITY TO SEE FOR WORK BY DAY-LIGHT ALONE	ALL	WITH WINDOWS		WITHOUT WINDOWS		
		WITH SKYLIGHT	WITHOUT SKYLIGHT	WITH SKYLIGHT	GLASS SCREEN ONLY	NOTHING
	%	%	%	%	%	%
Well	57	68	58	57	15	—
Fairly well	23	21	23	22	30	—
Badly	11	4	12	11	10	—
Never by daylight alone	9	7	7	10	45	100
	100	100	100	100	100	100
Number in sample	1408	164	1147	54	20	23

Thus only about four workers in five considered that they could see well or fairly well for their work by daylight alone, while about one in five could either see only badly or not at all. Staff with both windows and a skylight were most satisfied.

Analysis of the answers to this question both by industry and by the number of office workers employed shows no significant differences and an analysis of the answers by the type of work done by the informant produces no evidence of significant differences, except that 18 per cent of the machine operators, as compared with 9 per cent of the total, were never able to work by daylight alone.

FACTORS ASSOCIATED WITH THE ABILITY TO SEE BY DAYLIGHT ALONE

14. Tables 22 to 26 indicate the association between the workers' stated ability to see when working by daylight alone and certain factors derived from observations or measurements made by the investigators.

DIRECT DAYLIGHT

15. Investigators recorded whether or not the informant had direct daylight on his working plane. This observation was made by use of a mirror held on the desk or table top and information was obtained in respect of all but 7 of informants with windows: 79 per cent of these were found to have direct daylight. The association with ability to see is shown in the table below.

TABLE 22. DIRECT DAYLIGHT: ASSOCIATION WITH ABILITY TO SEE

ABILITY TO SEE BY DAYLIGHT ALONE	ALL WITH WINDOWS %	WHETHER DIRECT DAYLIGHT ON WORKING PLANE	
		YES %	NO %
Well	59	67	29
Fairly well	23	23	20
Badly	11	8	23
Never by daylight alone	7	2	28
	100	100	100
Number in sample (those with windows)	1311	1041	263

AMOUNT OF SKY VISIBLE THROUGH NEAREST WINDOW

16. Investigators were instructed to sit in the informant's working position and to record the proportional area of the nearest window occupied by sky, if this could be seen without turning the head more than 90° on either side of the normal forward-facing direction: otherwise, "nearest window not visible" was recorded.

TABLE 23. AMOUNT OF SKY VISIBLE THROUGH NEAREST WINDOW: ASSOCIATION WITH ABILITY TO SEE

ABILITY TO SEE BY DAYLIGHT ALONE	ALL WITH WINDOWS %	AMOUNT OF SKY VISIBLE THROUGH NEAREST WINDOW (PROPORTION OF WINDOW SPACE)				NEAREST WINDOW NOT VISIBLE %
		NO SKY %	0–$\frac{1}{3}$ %	$\frac{1}{3}$–$\frac{2}{3}$ %	MORE THAN $\frac{2}{3}$ %	
Well	59	33	54	66	77	52
Fairly well	23	23	25	24	18	24
Badly	11	22	16	8	4	11
Never by daylight alone	7	22	5	2	1	13
	100	100	100	100	100	100
Number in sample	1311	175	323	364	270	179

The association is very marked: 44 per cent of staff who were unable to see any sky through their nearest window found their daylight lighting definitely unsatisfactory compared with 5 per cent of those who could see two-thirds or more of sky.

ANGLE OF ELEVATION TO THE TOP OF NEAREST WINDOW

17. Investigators noted for each informant with a window: (i) The horizontal distance from the centre of the working plane to the nearest window; (ii) the height of the bottom of the window above floor level; and (iii) the height of the window from top to bottom. From these measurements it was possible to calculate (assuming 2 ft. 6 in. as the height of the working plane above floor level) the angle of elevation of the top of the nearest window from the subject's working plane for all subjects.

The association between this measure and ability to see is indicated in the following table which clearly shows the higher the angle the greater the proportion of workers who can see well.

TABLE 24. ANGLE OF ELEVATION OF TOP OF NEAREST WINDOW: ASSOCIATION WITH ABILITY TO SEE

ABILITY TO SEE BY DAYLIGHT ALONE	ALL WITH WINDOWS	ANGLE OF ELEVATION					
		UNDER 30°	30°–40°	40°–50°	50°–60°	60°–70°	OVER 70°
	%	%	%	%	%	%	%
Well	59	41	50	62	65	69	75
Fairly well	23	26	29	21	21	20	17
Badly	11	18	13	12	9	7	7
Never by daylight alone	7	15	8	5	5	4	1
	100	100	100	100	100	100	100
Number in sample	1311	259	206	229	237	260	120

RATIO OF TOTAL WINDOW AREA TO ROOM AREA

18. The table below shows the association between ability to see for work by daylight alone and one of the measures referred to on page 43 (see Table 14), and demonstrates the increasing satisfaction of the workers with improved ratios of window area to floor area.

TABLE 25. RATIO OF WINDOW AREA TO ROOM AREA: ASSOCIATION WITH ABILITY TO SEE

ABILITY TO SEE BY DAYLIGHT ALONE	ALL WITH WINDOWS	TOTAL WINDOW AREA OF ROOM / FLOOR AREA OF ROOM			
		UNDER ·1	·1–·2	·2–·3	·3 AND OVER
	%	%	%	%	%
Well	59	47	55	65	75
Fairly well	23	23	25	22	19
Badly	11	15	13	10	4
Never by daylight alone	7	15	7	3	2
	100	100	100	100	100
Number in sample	1311	205	588	315	203

DIRECTION IN WHICH WINDOWS FACE

19. Investigators were equipped with compasses and recorded the direction(s) in which the windows of the informant's room faced. 63 per cent of staff with windows worked in rooms whose windows faced in one direction only. In Table

26 the abilities to see of those having windows facing in one of the four cardinal compass directions are compared.

TABLE 26. DIRECTION IN WHICH WINDOWS FACE: ASSOCIATION WITH ABILITY TO SEE

ABILITY TO SEE BY DAYLIGHT ALONE	ALL DIRECTIONS	DIRECTION IN WHICH WINDOWS FACE (IF IN ONE DIRECTION ONLY) NEAREST CARDINAL COMPASS POINT			
	%	N %	W %	S %	E %
Well	57	54	53	62	60
Fairly well	23	23	27	23	21
Badly	12	15	11	8	12
Never by daylight alone	8	8	9	7	7
	100	100	100	100	100
Sample (those with windows facing one direction only)	830	222	172	227	209

The table suggests that those whose windows faced south or east were slightly better off than those whose windows faced north or west.

COMMENTS AND OPINIONS OF STAFF ON THE LIGHTING OF THEIR WORK BY DAYLIGHT

General comments

20. All informants were asked the question, "What, if anything, would you say is wrong with the lighting of your work by daylight alone?" The replies made to this question are classified in Table 27.

TABLE 27. COMMENTS ON THE DAYLIGHTING OF THE WORK

	COMMENTS	TOTAL	ABILITY TO SEE BY DAYLIGHT ALONE			
		%	WELL %	FAIRLY WELL %	BADLY %	NEVER %
A	"Too little/no daylight"	10	—	6	25	63
B	"Sitting too far from window, etc."	6	1	11	14	14
	Window obscured:					
C	(i) architectural obstruction	6	1	7	26	10
D	(ii) other ,,	2		2	6	2
E	Objects in room cause shadows	5	2	10	14	2
F	Window too small, badly placed	4	1	5	12	7
G	Light insufficient in dull weather	2	2	6	1	—
H	Daylight "too bright," "glare," etc.	1	2	2	—	—
	Miscellaneous comments	1	1	2	1	—
	No criticism made	63	90	49	1	2
		100	100	100	100	100
	Number in sample	1408	809	318	155	126

37 per cent of informants made specific criticisms of their lighting conditions —about one in ten of those who said that they could see well by daylight alone, about half of those saying "fairly well" and practically all of those saying "badly." Only 1 per cent of all workers mentioned glare, but subsequent questioning revealed that 16 per cent found the daylight glaring under certain conditions. (See Table 31.)

The great majority of comments—about 90 per cent—are concerned merely with the amount of daylight received, rather than with questions of comfort or quality of the lighting. It is only among those seeing well by daylight that complaints other than about quantity form any considerable proportion of the comments made. Since this question of the "quality" of daylight is of considerable interest, however, the relevant information obtained is considered separately in the next two sections.

"Glare"

21. In Table 27 (Group H) there have been grouped together under the general heading of "Daylight too bright, etc." all those comments made which referred to excessive brightness within the field of vision: this group comprises the comments made by 21 persons, about 1 per cent of the sample. They can be analysed as follows:

9 were references to discomfort caused by sun only.

4 were complaints that the subjects sometimes found the daylight "too bright" without further detail being given.

8 described in more detail conditions that apparently caused regular discomfort. These were:

a. The light shining through the stained glass top of the window, which the subject was facing, was found distracting: the colours "seemed to attract the eyes."
b. The papers with which the subject worked seemed "too brightly lit" in contrast with the surroundings.
c. The subject sat facing a window which was above her eye-level: she complained that she found it "glaring."
d. Another subject facing the nearest window complained that she "got the light in her eyes" in the early part of the morning.
e. Subject complained that papers on her desk "shone," and caused "glare."
f. The subject was sitting with back to the nearest window facing a white-tiled wall; found the "white shine" from the wall distracting.
g. Reflections from the keys of a typewriter were found "dazzling."
h. One subject, sitting sideways to the nearest window, found "the sharp contrast of bright on her left side and comparative darkness on her right side rather a strain."

It seems that only about one-half of one per cent of the sample considered regular glare conditions to be a major defect of the daylighting of their work. It is therefore at first somewhat surprising to find that, when subsequently asked the specific question "Do you ever find the daylight glaring?", 16 per cent of informants replied "Yes": but the answers of these informants to a further question about when they found it so explains this result. The answers have been classified and are summarised in Table 28.

TABLE 28. WHEN DAYLIGHT IS FOUND TO BE "GLARING"

COMMENT	%
"When sun is directly on work" "Shining directly into office," etc.	36
"When sun is particularly bright," etc.	22
"In summer," "When sun shines"	21
"In the afternoon"	8
"In the morning"	6
Miscellaneous comments	7
	100
Number in sample (office workers who find the daylight "glaring")	226

Obviously, most informants associated glare with sunlight only—about half of them, moreover, with special conditions of sunlight. The inference that "glare," in the sense in which it was understood, was regarded merely as an occasional problem is borne out by the fact that one-fifth of those who said they saw well for their work by daylight answered "Yes" to this question.

Of the 15 persons whose comments are classed as "miscellaneous" in the table, 10 described special conditions of sunlight, 2 made vague replies, and the remaining 3 referred to mixtures of artificial and natural light as the cause of glare.[1]

Sunlight

22. When asked if they ever had sunlight in their office, 59 per cent said that the sun occasionally shone into their office in winter, and of those who were at their present place of work in the previous summer, 73 per cent said that they had it in summer. A series of questions (Q. 13 in Questionnaire) was asked about the attitude towards sunlight in the office. In answer to the first question—"Do you prefer to work in a sunlit office or without sun?"—the replies summarized in the following Table were given.

TABLE 29. ATTITUDE TO SUNLIGHT IN OFFICE

WHETHER TO WORK WITH OR WITHOUT SUN PREFERRED	ALL	DOES THE SUN SHINE IN THE OFFICE IN WINTER?		DOES THE INFORMANT WEAR GLASSES?	
	%	YES %	NO %	YES %	NO %
With sun (unqualified)	59	63	53	55	63
With sun (qualified)	25	26	23	27	23
Without sun	14	9	20	15	12
No preference	2	2	4	3	2
	100	100	100	100	100
Number in sample	1408	830	578	662	746

It will be seen that those who sometimes have sun in their offices during winter show a significantly greater proportion definitely preferring sunlight and a considerably smaller proportion opposed to it than those who do not have sunlight. In other words, 89 per cent of those who have sun all the year round prefer it but some qualify this preference.

Persons who wore glasses were somewhat less in favour of direct sunlight than those who did not.

Those who stated any preference for sun were asked for what part of the day they preferred it, (*a*) in summer and (*b*) in winter. The results were as follows.

[1] Glare, especially sky glare, is often not consciously observed by people and the Committee is of opinion, therefore, that the information obtained does not give a true indication of the proportion of staff working under conditions giving rise to glare.

TABLE 30. WHEN SUN IN THE OFFICE IS PREFERRED

TIME	INFORMANTS PREFERRING SUN		ALL INFORMANTS	
	(a) IN SUMMER %	(b) IN WINTER %	(a) IN SUMMER %	(b) IN WINTER %
All day	65	83	54	70
Morning only	27	9	23	8
Afternoon only	5	5	4	4
No particular time preferred	3	3	3	2
Sun not preferred	—	—	16	16
	100	100	100	100
Number in sample	1180	1180	1408	1408

Thus 54 per cent of persons interviewed said that they would like sun in their offices all day in summer and 70 per cent all day in winter, though about a third of these made reservations as detailed below. Some informants made more than one reservation: the table gives the proportion of informants making each reservation.

TABLE 31. RESERVATIONS MADE BY THOSE STATING A QUALIFIED PREFERENCE FOR SUN

RESERVATIONS	INFORMANTS WITH QUALIFIED PREFERENCE FOR SUN %	ALL INFORMANTS %
Not directly on work	34	9
Not in eyes	30	7
Not too strong, bright, glaring	27	6
Not too hot	20	5
Other reservations	6	2
Qualified preference for sun not stated	—	75
	100	100
Number in sample	350	1408

The majority of the reservations could probably be met if sun-blinds or curtains were provided. Information on this point was obtained in respect of two-thirds of the informants, and of these only 28 per cent were found to have blinds, etc., available. Five persons making reservations classed under "other reservations" in Table 31 specified their necessity. The question about whether blinds, etc., were provided was suggested too late to be printed on the questionnaire: it was consequently overlooked by some investigators. This explains why only two-thirds of the sample were questioned.

The following reasons were given by those who were unconditionally opposed to having sun in the office: some gave more than one reason.

TABLE 32. REASONS GIVEN BY THOSE PREFERRING NO SUN

REASONS	INFORMANTS PREFERRING NO SUN %	ALL INFORMANTS %
Causes glare	48	7
Too hot	29	4
Causes dazzle	24	3
Distracting	5	1
Tiring, causes eyestrain, etc.	5	1
Other reasons	8	1
Sun preferred	—	84
	100	100
Number in sample	193	1408

PART IV—ARTIFICIAL LIGHTING

TYPE OF LIGHTING

23. Tables 33 and 34 below give details of the lighting provided.

TABLE 33

TYPE OF LIGHTING	%
Incandescent	76
Fluorescent	19
Incandescent and fluorescent together	5
	100
Sample (office workers)	1408

TABLE 34

TYPES OF FITTING	%
Direct	68
General	28
Indirect	4
	100
Sample (office workers)	1408

Note.—To avoid a misinterpretation of these figures it is necessary to point out that the data is based on the number of informants and not the number of offices or number of fittings. The interpretations of type of fitting used by the investigators do not necessarily comply with the B.S.I. definitions. (See Instructions to Investigators, p. 63.)

Nearly one-quarter of the informants worked in rooms in which fluorescent lighting was installed. These fittings were of the "cupped ends" type in 84 per cent of cases, 16 per cent being of the "exposed ends" type.

INDEPENDENT LIGHTS

24. Investigators recorded whether or not the informant was able to control his light independently of the main lighting. 9 per cent of the workers had desk lights, 27 per cent had hanging lights which they could control independently, and the remaining 64 per cent had no independent control of their lights.

INTENSITY

25. Investigators were instructed to take a light-meter reading in the informant's working plane if the main artificial lights of the room were on at the time of the interview: readings were taken in respect of 682 informants. A comparison between this group and all informants in respect of ability to see by artificial light (see Tables 40 and 41) shows no significant differences between the distributions. It was clearly not practicable—nor was it desirable for the purposes of the "daylight" section of the inquiry—to have all the interviews made late enough in the afternoon to ensure staffs would be entirely dependent on artificial light at the time when the light-meter readings were taken. It is probable, therefore, that a considerable proportion of the higher readings obtained were caused by the combination of daylight with artificial light. In order to indicate the extent of this interference the summary of all the readings obtained, given in the first column of the table below, has been compared with the distribution of readings obtained for those previously classified as having no direct daylight.

TABLE 35. INTENSITY OF LIGHT ON WORKING PLANE

(Readings taken if main lights on)

INTENSITY IN LM./SQ. FT.	ALL READINGS %	READINGS FOR INFORMANTS HAVING NO DIRECT DAYLIGHT ON WORKING PLANE %
0–4	9	11
5–9	28	37
10–14	21	20
15–19	16	14
20–24	8	5
25–29	6	6
30–34	3	2
35 and over	9	5
	100	100
Number in sample	682	213
Mean of readings lm./sq. ft.	15·4	12·8
Mode of readings lm./sq. ft.	8·5	8·0

It is possible that some of the readings summarized in the second column of the above table were influenced by indirect daylight, but evidently about half of those who were chiefly dependent on artificial light were working in intensities below 10 foot-candles. Owing to the presence in both distributions of a small proportion of extremely high values the average reading is not a very significant measure of central tendency: the most frequently observed reading was in fact 8 foot-candles.

26. Because of the small number of persons doing particular types of work in the part of the sample for whom light-meter readings were taken, it is not possible to give precise estimates of the level of illumination under which each particular type of work was done: and, as noted, mean readings are not a useful measure. The following table will, however, give a rough indication of the comparative position.

TABLE 36. COMPARATIVE LEVELS OF ILLUMINATION OBSERVED FOR CERTAIN TYPES OF OFFICE WORK

TYPE OF WORK	PROPORTION OF READINGS UNDER 10 LM./SQ. FT. %	MODE OF READINGS	NUMBER IN SAMPLE (READINGS TAKEN)
Drawing	3	32·5	32
Typing	29	10·9	150
Operating machine	31	11·7	55
Ledger	36	9·0	73
General clerical	47	8·0	333
All types of work	37	8·5	682

Draughtsmen were clearly very much better off than other types of staff. The proportion of typists working with less than 10 lm./sq. ft. was significantly lower than the proportion of the total: general clerical workers—who come at the bottom of the scale—show a proportion of "under 10's" significantly higher than the average and have a modal reading considerably under 10, while ledger clerks come next to the bottom, also with a modal reading less than 10.

USE OF ARTIFICIAL LIGHT

27. All were asked for what proportions of the morning and the afternoon the lights in their room were normally on at that time of the year. (Questions 4 and 5.) The information is summarized in Table 37.

TABLE 37. THE EXTENT TO WHICH ARTIFICIAL LIGHTS ARE USED (FEB./MARCH)

PROPORTION OF AFTERNOON DURING WHICH LIGHTS ON	PROPORTION OF MORNING DURING WHICH LIGHTS ON			TOTALS
	ALL THE MORNING %	PART OF THE MORNING %	NOT AT ALL IN MORNING %	%
All afternoon	22	4	—	26
From about 3.0 onwards	1	8	5	14
From about 4.0 onwards	1	11	31	43
Not at all in afternoon	—	1	16	17
Totals	24	24	52	100

(Sample, 1408=100 per cent.)

It will be seen that 22 per cent were working in rooms in which the lights were on all day, while 16 per cent did not normally have the lights on at all during the day.

If certain broad assumptions are made we can obtain from these data some estimate of the proportions of office staff having their lights on at different periods in the day at that time of the year. If we assume (i) that the average times of starting and finishing work were 9 a.m. and 5.30 p.m. respectively (see Table 10), (ii) that the average lunch-break was from 1 p.m. to 2 p.m., and (iii) that use of light for "part of the morning" implied an average period of from 9 o'clock to 10.30, estimates can be made as shown in Tables 38 and 39.

TABLE 38. ESTIMATED PROPORTIONS OF OFFICE WORKERS HAVING LIGHTS ON AT GIVEN PERIODS OF THE DAY (FEB./MARCH)

PERIOD OF DAY	ESTIMATED PROPORTION HAVING LIGHTS ON %
9–10.30 a.m.	48
10.30 a.m.–1 p.m.	24
2 p.m.–3 p.m.	26
3 p.m.–4 p.m.	40
4 p.m.–5.30 p.m.	83
Number in sample	1408

TABLE 39. ESTIMATED HOURS PER DAY FOR WHICH LIGHTS USED (FEB./MARCH)

HOURS PER DAY FOR WHICH LIGHTS USED	%
Lights not used at all	16
Lights used up to 3 hours	48
Lights used over 3 and up to 6 hours	13
Lights used over 6 and up to 7½ hours	23
	100
Number in sample	1408

EFFECTIVENESS OF ARTIFICIAL LIGHT

28. All were asked, "Are you able to see well, fairly well or badly when working by artificial light?" The replies are summarized in Table 40.

TABLE 40. ABILITY TO SEE BY ARTIFICIAL LIGHT

ABILITY TO SEE	ALL TYPES	TYPE OF LIGHTING			TYPE OF LIGHT-FITTING		
		FLUOR-ESCENT	FLUOR-ESCENT AND INCAND.	INCAND. ALONE	DIRECT	GENERAL	INDIRECT
	%	%	%	%	%	%	%
Well	59	81	71	53	60	59	40
Fairly well	33	17	25	38	32	35	52
Badly	8	2	4	9	8	6	8
	100	100	100	100	100	100	100
Number in sample	1408	262	71	1075	961	397	50

Six out of ten said that they saw well for their work by artificial light. This proportion rises to eight out of ten for those working by fluorescent lighting, while only slightly more than half of those with incandescent lighting alone said that they could see well. The figures for fluorescent lighting may of course reflect a general improvement in the design of the installations.

There is no evidence of a significant difference in "ability to see" between those with "direct" and "general" types of fitting. While the numbers with "indirect" fittings is rather small for comparison, it is probable that the lower proportion seeing well with this type is a significant difference.

TABLE 41. INTENSITY ON WORKING PLANE: ASSOCIATION WITH ABILITY TO SEE

ABILITY TO SEE	ALL READINGS	INTENSITY OF LIGHT ON WORKING PLANE (READING IN LM./SQ. FT.)		
		UP TO 9	10–19	20 AND OVER
	%	%	%	%
Well	62	54	66	68
Fairly well	31	39	27	25
Badly	7	7	7	7
	100	100	100	100
Number in sample	682	257	250	175

The most striking feature of Table 41 is the stability of the proportion seeing "badly" between the groups with low, medium, and high intensities of light. The reason for this might well be that factors not directly attributable to the lighting, such as poor vision, may be at work and are not fully compensated for by increases in the level of illumination. The increase in the numbers seeing well when the light is increased appears to agree with what would be expected from changes in the illumination over the relatively limited range of values investigated.

COMMENTS AND OPINIONS ON ARTIFICIAL LIGHTING

General Comments

29. All informants were asked, "What, if anything, would you say is wrong with the artificial light?"

Replies are classified in Table 42.

TABLE 42. WORKERS' COMMENTS ON THE ARTIFICIAL LIGHTING

COMMENTS	%
Lights badly placed	17
Lights not strong enough	8
Light too glaring	6
Causes eyestrain, headaches, etc.	3
Would prefer no artificial light	2
Would prefer different type	3
Miscellaneous comments	2
No comments made	59
	100
Number in sample	1408

Thus 41 per cent of workers made critical comments on the artificial lighting of their work—and a large proportion made no comments at all.

In contrast with the criticisms made about daylight conditions only in one-fifth of the comments made about artificial lighting is the suggestion of insufficient quantity dominant. Almost twice as many people complained of bad positions for their lights as complained about the amount of light. This was the most common complaint and will be dealt with in greater detail below.

The third most common complaint, made by 6 per cent of staff, was that they found the light too glaring. Thus glare under artificial lighting conditions appears to be considered more serious than under daylight conditions, where the proportion complaining directly of glare is 1 per cent.

It is interesting to note that the 3 per cent complaining of eyestrain are divided proportionately between those with and without fluorescent lighting.

Of those expressing a preference for another type of lighting 17 said they disliked fluorescent lighting, 6 complaining of its colour. However, 16 persons with incandescent lighting expressed a preference for fluorescent lighting, while a further 5 complained of the yellowness of their incandescent lighting.

Among the miscellaneous group of answers were 7 who complained of the effects of combined daylight and artificial light, *e.g.* "daylight sufficient but artificial burning, so there are shadows and blurs of light."

Positioning of lights

30. In answer to the general question of the previous section 17 per cent of staff said their lights were badly placed. When asked directly, "Do you think the lights are badly placed?" the percentage making this complaint rose to 27 per cent. This might be expected since badly placed lights could account for a number of other complaints appearing in Table 42 above.

Those complaining that their lights were badly placed were further asked to say what was wrong.

TABLE 43. POSITIONING OF LIGHTS

WHAT IS WRONG WITH THE POSITION OF THE LIGHTS	%
Lights too high, too far away	9
Lights behind (shadows)	5
Lights needed over work	8
Lights needed to be behind	3
Desk lamp needed	2
More lights needed	1
Miscellaneous	1
Nothing wrong	73
	100 *
Number in sample	1408

* The percentages in the table add to more than 100 since some workers gave a reason besides asking for a desk lamp.

Modifications to their light-fittings made by the workers

31. Investigators were instructed to record briefly any modifications which a worker had made to his light fitting.

33 people were found to have made modifications and all of them were using incandescent lights alone: they represented 2·3 per cent of the sample and 3·1 per cent of those working by incandescent light alone.

The majority of the modification (26) were attempts to alter the position of the light and usually involved the light being drawn nearer to the desk by string attached to the flex: the remaining 7 were attempts to modify the brightness or distribution of the light, generally by means of paper or cardboard shades.

In answer to Question 10—"What, if anything, would you say is wrong with the artificial light?"—10 of these people made no comment, and of the remainder 9 complained of bad placing, 5 of glare, 5 made comments indicating insufficient power, 1 complained of eyestrain, and 3 made other comments.

The number of people who had made modifications to their lights is too small to permit detailed statistical comparison with the rest of the sample, but it seems that 4 out of the 26 workers (*i.e.* 15 per cent) who had altered the position of their lights complained of glare compared with slightly less than 6 per cent of all others.

Other comments

32. As a final question the informants were asked, "Have you any other comments about the lighting of your work?" About one-third of all persons made some comment although many merely repeated what they had said earlier. However, 12 per cent of the sample indicated a preference for some type of artificial lighting other than what they had. It is interesting to examine these preferences.

The largest group, 81 people, said they would like desk lamps. A group of 64 with incandescent lighting said they would prefer fluorescent lighting—one lady referred to it as "nylon lighting." Of 11 persons wishing to change their fluorescent lighting, 4 wished to change its colour (not white) while 7 wanted incandescent lighting.

ACKNOWLEDGMENTS

The officers of the Social Survey responsible for the preparation of this data wish to record their appreciation of the co-operation of employers and employees for these studies.

PART VI—THE QUESTIONNAIRE

A SURVEY OF LIGHTING IN OFFICES

(i) Interviewer ....

Authorisation Number ....

(ii) District ....

(iii) Region ....

1	2	3
4	5	6
7	8	9
10	11	12

(iv) INFORMANT'S SEX

Male	Y
Female	X

(v) Date ....

(vi) Time of interview ....

(vii) INFORMANT'S AGE

Up to 29	0
30–39	1
40–49	2
50 and over	3

(viii) INFORMANT'S INDUSTRY

Manufacturing	4
National and Local Government	5
Others	6

(ix) Serial Number ....

(x) NO. OF OFFICE WORKERS EMPLOYED

Up to 5	Y
6–10	X
11–15	0
16–20	1
21–30	2
31–50	3
Over 50	4

(xi) Does informant wear glasses?

Yes	7
No	8

QUESTIONS TO BE ANSWERED BY INFORMANT

1. What kind of work do you do mainly?

Typing	Y
Ledger	X
Filing	0
Drawing	1
Operating machine	2
General clerical	3
Other (specify)	4

2. What hours do you work at this time of the year?

From		*To*	
8 a.m. or earlier	1	4 p.m. or earlier	1
8.15 a.m.	2	4.15 p.m.	2
8.30 a.m.	3	4.30 p.m.	3
8.45 a.m.	4	4.45 p.m.	4
9.0 a.m.	5	5.0 p.m.	5
9.15 a.m.	6	5.15 p.m.	6
9.30 a.m.	7	5.30 p.m.	7
9.45 a.m.	8	5.45 p.m.	8
10 a.m. or later	9	6 p.m. or later	9

3. Do you generally have the lights on during the summer?

Yes	Y
No	X
Don't know	0

4. At this time of the year do you normally have a light on?

PROMPT All the morning	Y
Part of the morning	X
Not at all normally	0

5. And in the afternoon do you have it on—

All afternoon	5
PROMPT From about 3 onwards	6
From about 4 onwards	7
Not at all normally	8

6. Are you able to see well, fairly well, or badly when working by daylight alone?

Well	Y
Fairly well	X
Badly	0
Never by daylight alone	1

7. What, if anything, would you say is wrong with the lighting of your work by daylight alone?

Y	X	0
1	2	3
4	5	6
7	8	9

8. Do you ever find the daylight glaring?

Yes	2
No	3

(a) If *Yes* (2), When?

D.N.A. Y

	X	0
1	2	3
4	5	6
7	8	9

9. Are you able to see well, fairly well, or badly when working by artificial light?

Well	4
Fairly well	5
Badly	6
Never by artificial light	7

10. What, if anything, would you say is wrong with the artificial light?

Y	X	0
1	2	3
4	5	6
7	8	9

11. Do you think the lights are badly placed?
Yes 8
No 9
(a) If *Yes* (8), what is wrong?
D.N.A. 9

Y	X	0
1	2	3
4	5	6
7	8	

12. Does the sun shine into your office at all?
(a) in summer { Yes Y
No X
Not here in summer 0
(b) in winter { Yes 1
No 2

13. Do you prefer to work in a sunlit office or without sun?
With sun (unqualified) 3
NO PROMPT With sun (qualified) 4
Without sun 5
No preference 6
(a) If *with sun (qualified)* (4)
Qualifications:—
D.N.A. Y
Not directly on work X
NO PROMPT Not in eyes 0
Not too strong 1
Not too hot 2
Other (specify) 3
(b) If *with sun* (3, 4) do you prefer the sun in the morning only, in afternoon only, or all day in summer? and in winter?

	Summer	*Winter*
D.N.A.	4	Y
Morning only	5	X
Afternoon only	6	0
All day	7	1
Don't know	8	3

(c) If *without sun* (5), why?
D.N.A. 4
NO PROMPT Dazzle 5
Glare 6
Too hot 7
Other (specify) 8

14. Have you any other comments about the lighting of your work?

Y	X	0
1	2	3
4	5	6
7	8	9

QUESTIONS TO BE ANSWERED BY INVESTIGATORS

15. How many people normally work in this room?

Y	X	0
1	2	3
4	5	6
7	8	9

16. Are the walls light, medium, or dark?
Light Y
Medium X
Dark 0

17. Is there a skylight?
Yes 1
No 2

18. Describe the light fittings:—

(a) Fluorescent	3
Incandescent	4
Both	5
If *Fluorescent* (3, 5)	
D.N.A.	6
Exposed ends	7
Cupped ends	8
(b) Direct	Y
Indirect	X
General	o
(c) No. of lights..	—

Description:—

19. Can the worker control his light independently of the main lighting?

Yes, desklight	1
Yes, hanging light	2
No	3

TAKE COMPASS READINGS FOR QS. 20, 22, 23

20. Which direction does the worker face?

North	4
East	5
South	6
West	7

21. Are there any windows?

Yes	8
No	9

IF WINDOWS, ASK QS. 22–26
IF NO WINDOWS, GO ON TO Q. 27

22. In which directions do the windows face?

(a) North	Y
East	X
South	o
West	1
(b) One direction	2
Two directions	3
Three directions	4
Four directions	5

23. Is worker

Facing nearest window	6
Sideways to nearest window	7
Back to nearest window	8

PUT YOURSELF IN INFORMANT'S WORKING POSITION

24. Looking at nearest window, how much sky can you see through the windows?

No sky	Y
0–⅓ of window space	X
⅓–⅔ of window space	o
More than ⅔ of window space	1
No windows visible	2

25. Describe the view through the nearest window as seen from informant's working position.

(a) Clear glass	3
Partly clear glass	4
No clear glass	5
No windows visible	6
(b) Movement	7
No movement	8
No windows visible	9
(c) Long view	Y
Short view	X
No view	o
(d) Pleasant	1
Not pleasant	2
No view	3

USE MIRROR FOR Q. 26

26. Is work done in direct daylight?
    Yes, direct daylight 4
    No 5
    Too dark to find out 6

27. Are any of the main lights on?
    Yes 7
    No 8

28. Is the worker's own (independent) light on?
    Yes Y
    No X
    No independent light o

IF ANY LIGHTS ON—
USE LIGHTMETER FOR QS. 29, 30

29. Put lightmeter on working plane and take reading
    Reading in footcandles, *i.e.* lm./sq. ft. .... —

    Taken without shield 1
        with shield 2

30. If *Yes* to Q. 28 (Y), independent light, take another reading with it switched off
    D.N.A. Y
    Reading in footcandles, *i.e.* lm./sq. ft. .... —

WINDOW MEASUREMENTS

31. Measure from floor to where glass begins
    No. of feet.............................. —

32. Measure height of window (from where glass begins)
    No. of feet.............................. —

33. Measure from where the glass ends to ceiling
    No. of feet.............................. —

34. Measure width of window
    No. of feet.............................. —

35. Total number of windows .... —

36. Equivalent window area
    No. of times .... —

37. Distance from window to worker
    No. of feet.............................. —

ROOM MEASUREMENTS

38. Length (side containing nearest window)
    No. of feet.............................. —

39. Breadth
    No. of feet.............................. —

INSTRUCTIONS TO INVESTIGATORS

PURPOSE

We are making this inquiry for the Committee on the Lighting of Buildings, which has been set up by the Department of Scientific and Industrial Research. We are going to find out, by taking measurements, how good or bad the general state of natural and artificial lighting in offices is at present. We are also going to relate those measurements to the worker's opinion so that satisfactory standards of lighting may be laid down for the guidance of architects designing office buildings in the future. The only way we can obtain accurate data on which to base our findings is by observation and measurement where this type of work is actually being done.

SAMPLING

You will be supplied with a list of office addresses, each of which has a serial number. Unless otherwise stated you have to interview *four* workers at each address. If there are less than four office workers in the firm you should interview all there are.

You must secure the co-operation of the management by explaining the purpose of the survey. You should point out that neither the name of the firm nor that of the worker will be recorded and that they form part of a randomly selected sample. You should go on to explain that you wish to select your four workers at random from a list in order to avoid bias. An attendance book, clocking-in cards, salary list, P.A.Y.E. cards, etc. would be suitable. Take them at roughly equal intervals from the list. In a small firm the manager might prefer to write out a list for you.

In general, the workers will be found in different rooms, but in a small firm or where there is a large general office, two or more may prove to be in the same room. Typists, clerks of all descriptions, draughtsmen, calculating machine operators, etc. are eligible. Try to interview them without the management being present.

It is most important that we obtain a representative sample and you should make every effort to secure your interviews at the address given. If, however, this should prove *absolutely* impossible, you may substitute another office of about the same size and in the same industry group. In this case the serial number to be used is that of the uncontacted address, but followed by an "S", *e.g.* 73S.

CLASSIFICATION

(x) You should find out from the management roughly how many office workers there are in (that branch of) the firm.

(xi) Are spectacles worn *for work*?

QUESTIONS FOR INFORMANTS—THESE SHOULD BE PUT BEFORE ANY MEASUREMENTS ARE MADE

Q. 2 This refers to a full normal working day. The times should be coded to the nearest quarter of an hour.

Q. 3 "Don't know" applies to those who have moved since the summer.

Q. 7–8 The order is important. Do not prompt at all for Q. 7, the answer may be "nothing."

Q. 10–11 Again the order is important. Do not prompt at all for Q. 10, the answer may again be "nothing."

Q. 13 No prompting.

Q. 14 Please give any comments as fully as possible. You may write right across the bottom of the schedule.

Q. 15 This question has had to be put on the inside page to help the coding section. You should write in the number.

QUESTIONS FOR YOU—ASK THE OTHER QUESTIONS FIRST

Q. 16 If the wall is not of one colour only, consider the upper half. The pieces of cardboard will help you to decide which code to use. If the upper part of the walls consists of glass screens (not windows), make a note of this.

Q. 17 A skylight should be recorded only if it lets in light. If it is blacked-out the answer is "no."

Q. 18 a. Fluorescent electric lights are those long glass tubes. All other electric lights are incandescent. If you find any gas lighting, make a note of it.

The fluorescent tube has "cupped ends" when there is about 3 to 4 inches of metal at each end of the glass tube.

b. This refers to the main lighting. If the lighting is "Direct," most of it is going downwards; if "Indirect," most of it is going up towards the ceiling and being reflected down from the ceiling. If it is "General" it appears to give out light equally all round.

c. The total number of lights.

Under description, give any unusual features of the lighting. In particular you should note any modifications made to the lighting, *i.e.* a piece of paper stuck on a desk lamp.

COMPASS READINGS

Do not place the compass on or near your lightmeter or a metal object

Hold it in your hand. Rotate the case until the north pointing needle is over N. You can then determine which direction the windows (Q. 22) and the worker (Q. 20) face.

Q. 20 One code only, *i.e.* you must decide whether it is more nearly north than east.

Q. 21 If there are no windows, you omit Qs. 22, 23, 24, 25, and 26.

Q. 22 If the windows face in "one direction" then you can only have one code for (a). If the windows face in "two directions" then you must have two codes ringed in (a).

Q. 23 The "nearest window" will be the one nearest to the individual's work.

Q. 24 Do not bend forward, but sit as the worker would. You may turn the head to the left or the right, but only the head.

Q. 25 b. Can you see people or traffic moving outside?

c. A short view is just across the road.

d. Worker's opinion.

Q. 26 USING THE MIRROR

Hold the mirror in the working plane and tilt it until by looking into it you can see the reflection of "the nearest window." If in this reflection you can see some sky, the answer is "Yes, direct daylight."

Q. 29 USING THE LIGHTMETER—IF ANY LIGHTS ARE ON

This instrument is fragile. It should be placed on the working plane and a reading taken. Care must be taken not to obstruct the light by bending over it or by shielding it with the hand. The small black shield with the three holes will not normally be required. Only use it if the pointer has moved too far to the right, *i.e.* in a very bright light. Don't forget to code "without shield," or "with shield."

WINDOW MEASUREMENTS

Measure to the nearest foot. For the height of the window you measure from the lowest position of the glass to the highest point of the glass. (This measurement will, of course, include some window bars, but this does not matter.) Measure the width of the window from where the glass begins on one side to where it ends on the other.

You will notice that if we add the three measurements of Qs. 31, 32, and 33 we get the height of the room.

Q. 35 A window, by our definition, must be vertical and communicate with the outside. A window looking out on to a passage, or another room, will not be recorded as a window. Neither will a glass screen.

Q. 36 We want to estimate the total window area. We shall know the area of the nearest window from Qs. 32 and 34. Suppose in addition to the "nearest window" there are two more of similar size, then the answer to Q. 36 is 3. But if there is only one more of similar size, also one about half the size of the "nearest," then the answer is $2\frac{1}{2}$.

Q. 37 This is the *horizontal* distance from the middle of the window ledge to over the working plane.

ROOM MEASUREMENTS

Measure to the nearest foot. Get someone to hold the end of the tape against the wall at a convenient height about half-way along one side of the room and measure to the opposite wall. Do not include small recesses in your measurements.

Q. 38 Length is the side containing the "nearest window." If there is no window, the length is the longest side.

DISTRICTS IN WHICH INTERVIEWS TOOK PLACE

Aberdeen
Aylesbury

Banbury
Basford R.D.
Bath
Birkenhead
Birmingham
Blackpool
Bolton
Bootle
Bradford
Bristol
Burnley

Cambridge
Cardiff
Castleford
Chatham
Chelmsford
Chester
Chester-le-Street
Chesterfield
Consett
Coventry
Crewe

Darlington
Darwen
Devizes
Dorking
Dorking R.D.

Ebbw Vale
Edinburgh
Ellesmere Port

Exeter
Exmouth

Glasgow
Gloucester
Grantham
Guildford

Harrogate
Hull

Ipswich

Kidderminster

Leamington
Leatherhead
Leeds
Leicester
Liverpool
Llandudno
London (Greater)
Lytham St. Annes

Maidenhead
Maidstone
Manchester
Middlesbrough
Morecambe

Nelson
Newark
Newcastle
Newmarket
Newport
Newton Abbot

Norwich
Nottingham

Ongar
Oxford

Plymouth
Pontefract
Pontypool
Preston

Reading
Rugby
Runcorn R.D.

St. Helens
Salford
Samford R.D.
Sheffield
Slough
Stafford
Stalybridge
Stoke-on-Trent
Sunderland R.D.

Tarvin R.D.
Tonbridge
Tonbridge R.D.
Torquay

Walsall
Widnes
Wolverhampton
Wrexham

York

APPENDIX II

A SUMMARY OF EVIDENCE ABOUT OFFICE LIGHTING

1. As acknowledged in the preamble to our Report the Committee received evidence concerning the lighting of office buildings from representatives of staff associations, from architects, and surveyors. It is not possible to include a detailed review of their remarks, but the following notes contain their main points, in addition to those already mentioned in the body of the Report.

STAFF OPINIONS ABOUT OFFICE LIGHTING

2. *Daylight.* In reply to questions about daylight the representatives said that the majority of staff want adequate natural light. They all considered the absence

of daylight a disadvantage to health although their objections were less strong if inadequate daylight is effectively supplemented by good artificial light. A view through a window was also considered important. There seemed strong preferences among some staff, particularly in congested city areas, for rooms on upper floors, probably because of improved lighting and less traffic noise.

3. *Artificial Light.* The representatives said that staff strongly dislike working wholly under artificial light during daytime, but where it is unavoidable, fluorescent light is generally preferred. The direction of either natural or artificial light preferred depends upon the type of work. For some office tasks it is preferred from the left or from overhead. On the whole, a good general light is preferred, supplemented by desk lights as and when required, to suit individual needs. Detailed evidence was also supplied about the lighting of drawing offices and banks, and some of this is incorporated in the body of the Report.

4. *Sunlight.* There was a general preference by staff for some sunlight, except in drawing offices. For rooms which receive natural light from the south, sun blinds are required.

5. *Legislation.* Witnesses strongly emphasized that in any new legislation affecting the erection of new office buildings, conditions should be imposed to secure good daylight, and one witness even expressed the hope that existing buildings should be modified or pulled down where they are deficient in natural daylight.

EVIDENCE ON THE DESIGN OF OFFICES

6. In reply to questions about the design of office buildings, the architects said that the London Building Act tends to cramp design by restricting, above first-floor level, the total window area to 50 per cent of the total elevation area. They added that it is possible to dispose the windows so that they form either horizontal or vertical bands. In view of the development of modern fire-resisting structures they felt that the statutory limitation is carried too far, and a general relaxation is desirable.

The witnesses considered that it is difficult to lay down hard and fast rules for the most suitable type of layout for office blocks, but there is no objection to internal courts or tooth-comb plan patterns where the site is large enough. There is a tendency to favour elimination of the small courts serving the ancillary spaces such as lavatories and to use artificial ventilation as in modern hotels.

The architects were also of the opinion that there is no such thing as a standard office in the City of London. It is the prevailing practice to provide clear open floor spaces which can be divided by standard partitions to meet individual tenants' needs. In planning open floors they were of the opinion that a grid layout of 21 ft. to 22 ft. 6 in. between stanchions is reasonable, as this is readily divisible into large or small offices. The surveyors, on the other hand, considered a 12-ft. structural bay ideal. The architects thought a daylight penetration of 16 ft. to 18 ft. desirable and that the whole area of a room should be well lit. They said a room 16 ft. deep with a 5-ft. corridor is almost standard practice.

The witnesses considered that reasonable storey heights in London are 14 to 15 ft. for the ground floor, 12 to 13 ft. for the first and second floors, and 11 ft. floor to floor for the upper floors.

OPINIONS ABOUT THE EFFECT OF LIGHT ON OFFICE RENTAL VALUES

7. *Daylight.* The architects emphasized that offices of all types need first-class daylight, and in their experience, property owners place considerable value on good daylight and were even prepared to lose a storey within the maximum permissible height of a building, if by that means they could improve the admission of daylight to the remainder. They described the successful building owner as "one who takes the free gift of daylight, protects it, combines it with his floor space to let or sell by the foot." As further evidence of the extent to which daylight is

now valued they mentioned that property owners are tending to charge as much rent for the top floors of office buildings as for the second floors.

All this was confirmed by the surveyors who said that from the lighting point of view good daylight is essential and is taken into account in valuing property. The Director of Lands and Accommodation of the Ministry of Works supported this by saying that his Department took into account the adequacy of the daylight when deciding the rental value of accommodation and that acceptance of an offer of accommodation depended upon the area of well-lit space available.

8. *Sunlight.* The surveyors were of the opinion that the demand for sunlight has no bearing on office values.

9. *Artificial Light.* The Director of Lands and Accommodation said there was a general liking amongst staff for fluorescent lighting but his Department did not regard it as an alternative to natural light. There was a definite disinclination by staff to work under artificial lighting all the time.

The Committee wished to discover to what extent artificial lighting could be made acceptable during the daytime and attempted to secure evidence about the value of a view from a window as distinct from its efficiency in admitting daylight. In contrast to the opinions of the staff associations, who valued a view, the surveyors considered that a view as such might be distracting and had no bearing on office values.

The architects said it was not possible to predetermine the position of artificial lighting outlets as each tenant preferred to make his own arrangements. The surveyors were of the opinion that this point did not affect office values, as the extra cost of wiring did not come into the picture.

APPENDIX III

AVERAGE DAYLIGHT ILLUMINATION THROUGHOUT THE YEAR

1. In the earlier Report we included a table prepared for us by the National Physical Laboratory giving the number of days in the year when the daylight illumination out of doors, excluding direct sunlight, drops below certain intensities. We now supplement this by further information of a similar kind made available to us by the National Physical Laboratory. This comprises: (i) a set of diagrams—Figs. 6–11—which show the average illumination over a period of 10 years at Teddington for different times of the day throughout each month of the year, and (ii) a chart—Fig. 12—showing, for any period of the year, the times at which, on the average, certain selected values of illumination occur.

2. From (i) the average intensity of illumination out of doors from unobstructed sky for any time of day can be easily ascertained and from (ii) the times and numbers of hours that the average illumination out of doors attains intensities of not less than 100, 250, and 500 lm./sq. ft. For instance, it will be seen that in January (Fig. 6) the average maximum illumination is approximately 750 lm./sq. ft. and occurs about 12.30 p.m., whereas in June (Fig. 8) the average maximum illumination is approximately 3,000 lm./sq. ft. occurring at a similar time. From Fig. 12 it will be seen that in June the illumination out of doors is not less than 500 lm./sq. ft. from approximately 5 a.m. to 7 p.m., a period of 14 hours, while in January the average illumination is not less than 500 lm./sq. ft. from approximately 9.30 a.m. to 2.30 p.m., a period of 5 hours only.

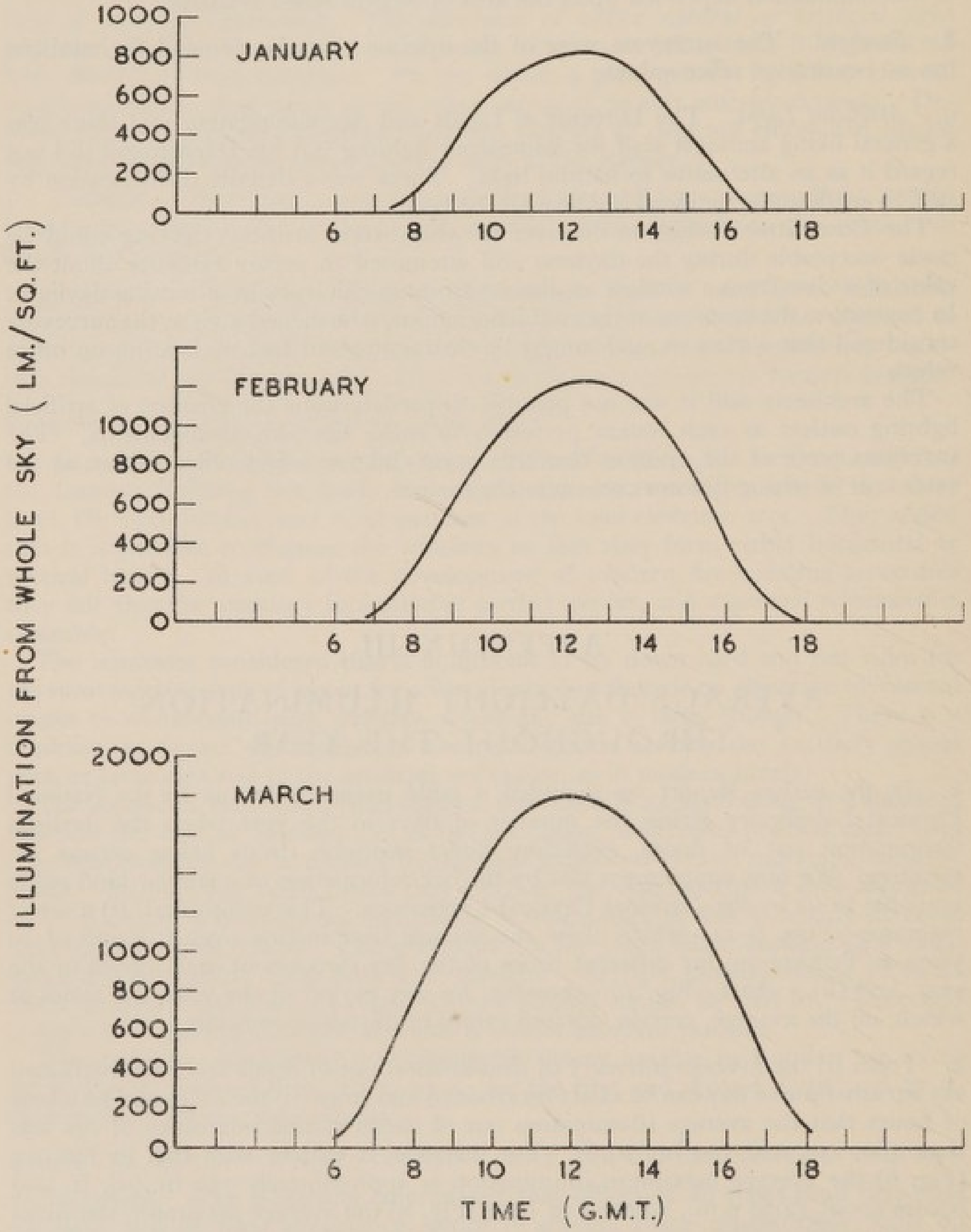
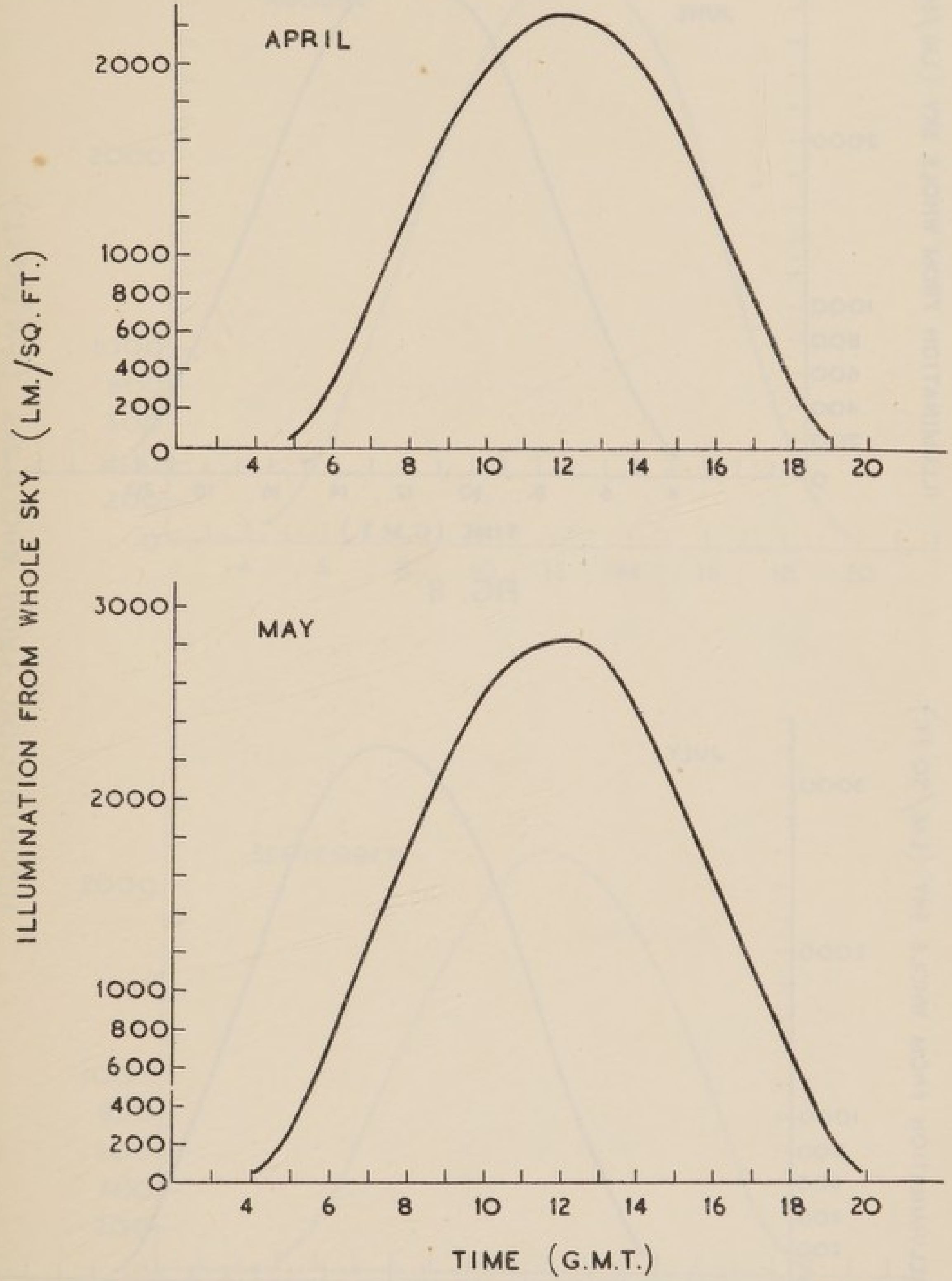

ILLUMINATION FROM WHOLE SKY (LM./SQ.FT.)
JANUARY
1000
800
600
400
200
0
6
8
10
12
14
16
18
FEBRUARY
1000
800
600
400
200
0
6
8
10
12
14
16
18
MARCH
2000
1000
800
600
400
200
0
6
8
10
12
14
16
18
TIME (G.M.T.)

FIG. 6



ILLUMINATION FROM WHOLE SKY (LM./SQ. FT.)
APRIL
2000
1000
800
600
400
200
0
4
6
8
10
12
14
16
18
20
MAY
3000
2000
1000
800
600
400
200
0
4
6
8
10
12
14
16
18
20
TIME (G.M.T.)

FIG. 7

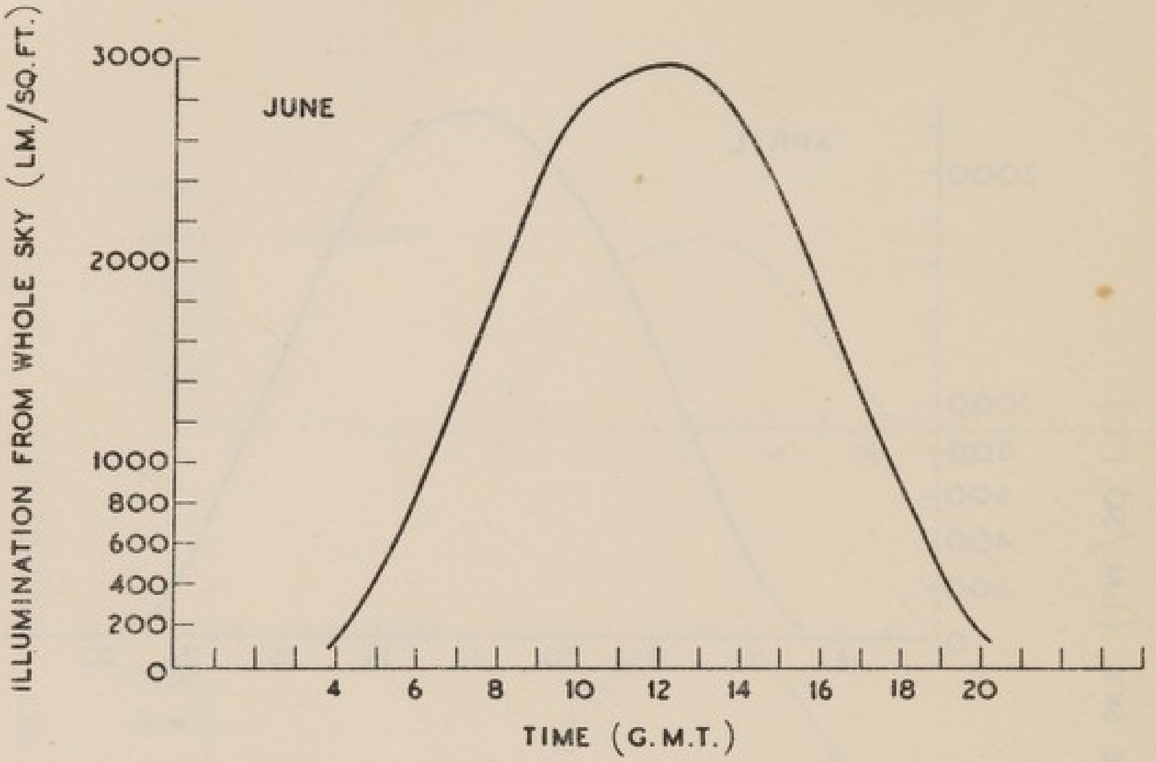

JUNE
ILLUMINATION FROM WHOLE SKY (LM./SQ.FT.)
3000
2000
1000
800
600
400
200
0
4
6
8
10
12
14
16
18
20
TIME (G.M.T.)

FIG. 8

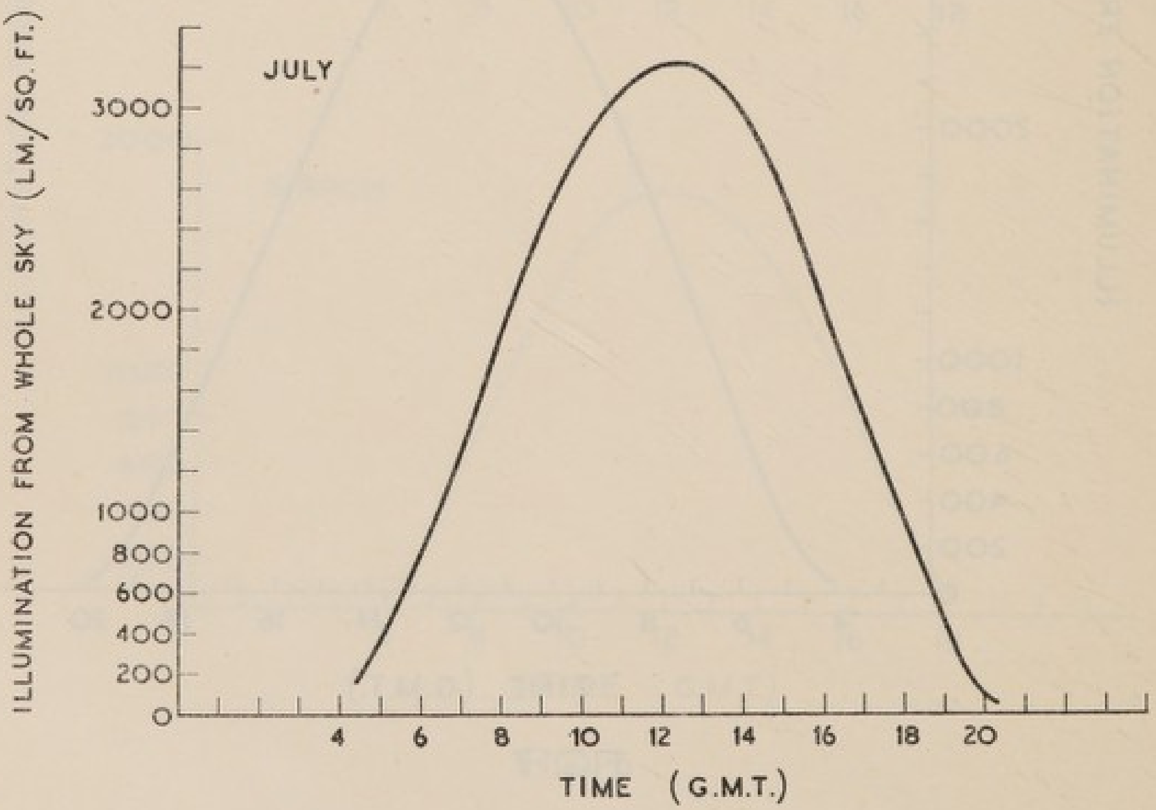

JULY
ILLUMINATION FROM WHOLE SKY (LM./SQ.FT.)
3000
2000
1000
800
600
400
200
0
4
6
8
10
12
14
16
18
20
TIME (G.M.T.)

FIG. 9

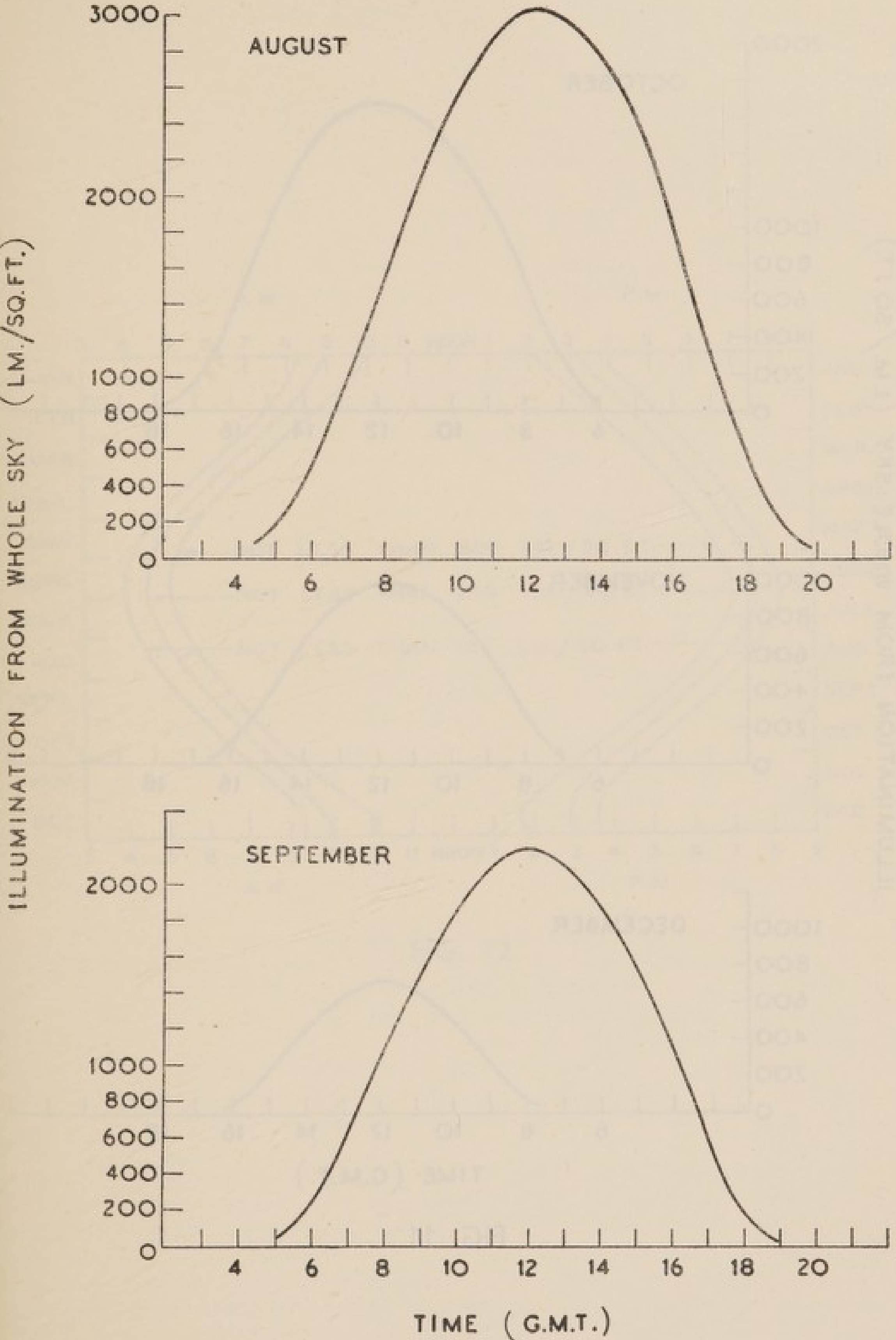

ILLUMINATION FROM WHOLE SKY (LM./SQ.FT.)
AUGUST
3000
2000
1000
800
600
400
200
0
4
6
8
10
12
14
16
18
20
SEPTEMBER
2000
1000
800
600
400
200
0
4
6
8
10
12
14
16
18
20
TIME (G.M.T.)

FIG. 10

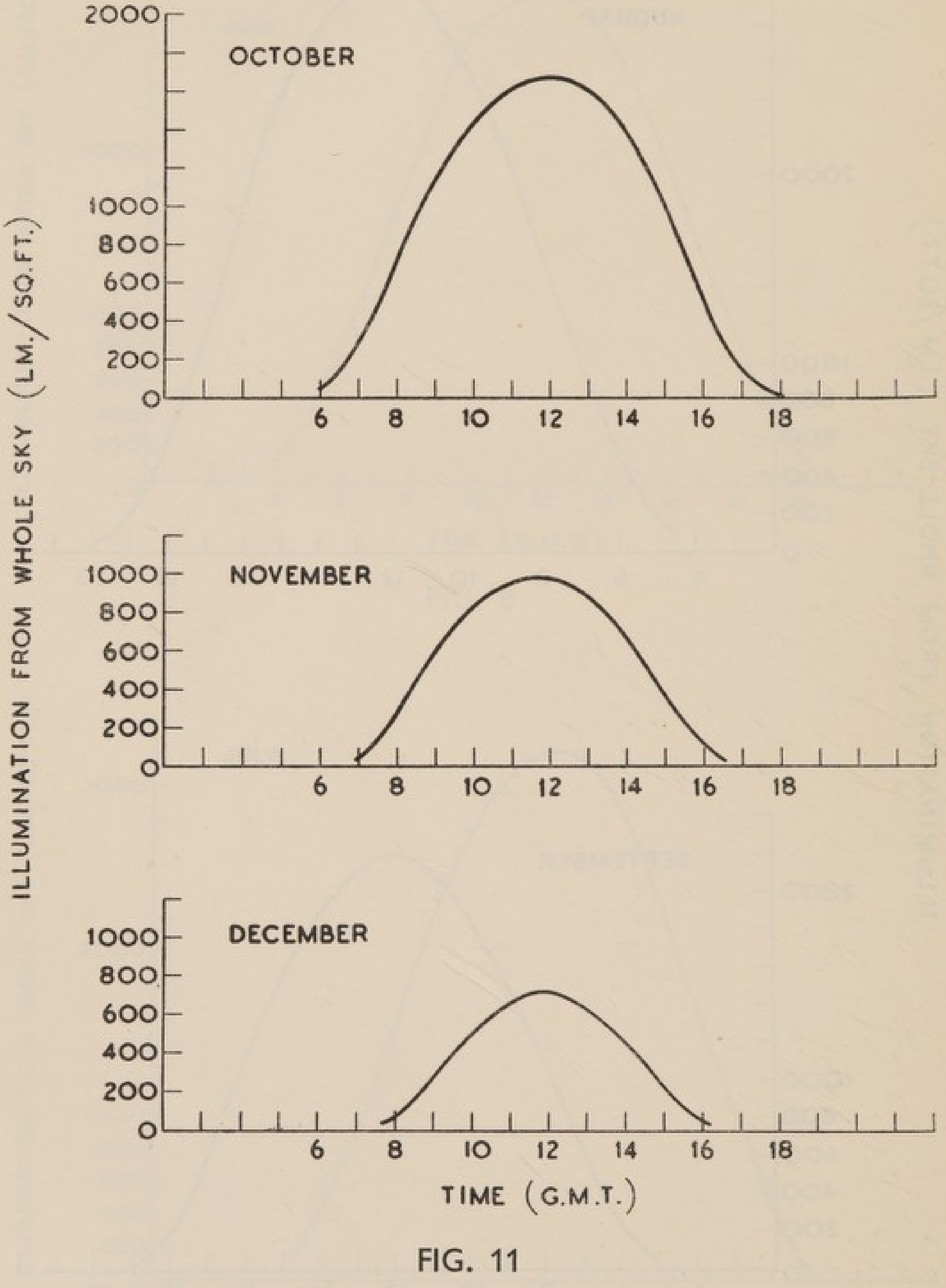

ILLUMINATION FROM WHOLE SKY (LM./SQ.FT.)
2000
1000
800
600
400
200
0
OCTOBER
6
8
10
12
14
16
18
NOVEMBER
DECEMBER
TIME (G.M.T.)

FIG. 11

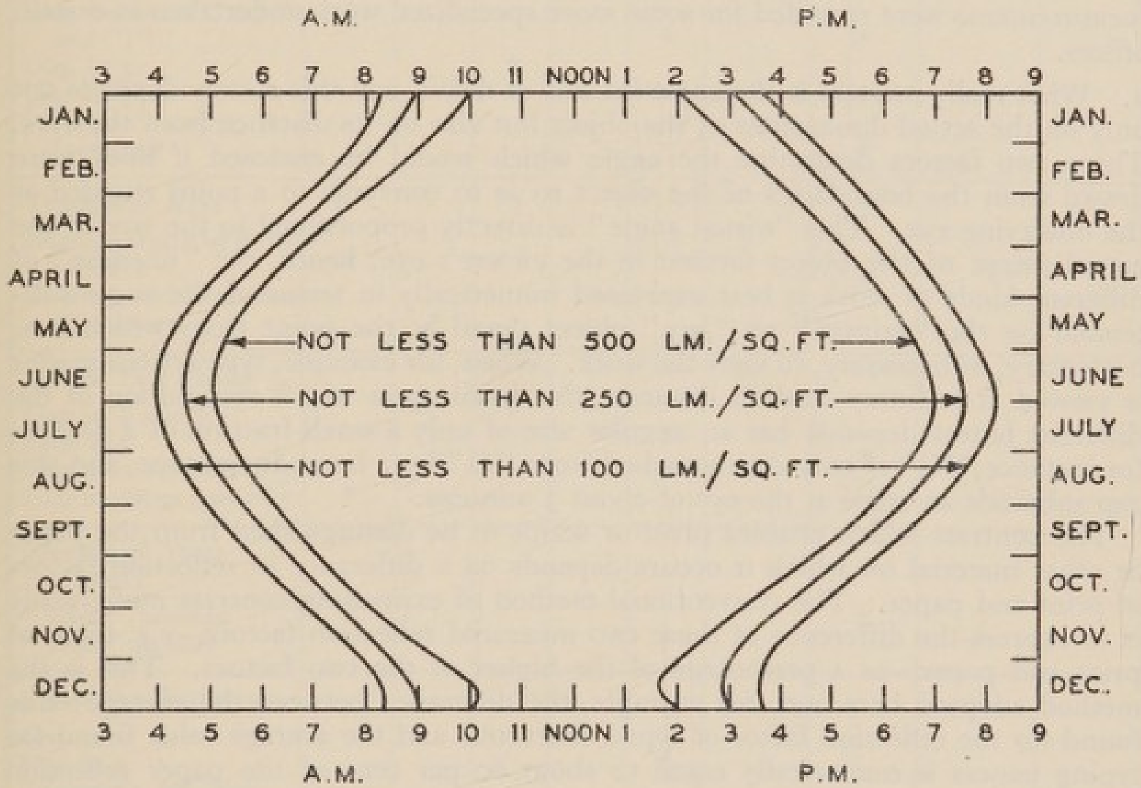

A.M.
P.M.
3 4 5 6 7 8 9 10 11 NOON 1 2 3 4 5 6 7 8 9
JAN.
FEB.
MAR.
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
NOT LESS THAN 500 LM./SQ.FT.
NOT LESS THAN 250 LM./SQ.FT.
NOT LESS THAN 100 LM./SQ.FT.

FIG. 12

APPENDIX IV

ANALYSIS OF THE VISUAL TASK IN OFFICE WORK

By H. C. Weston, F.I.E.S.

1. It is pointed out in the body of the Report that the visual severity of office tasks, and so the illumination that ought to be provided for them, largely depends on the size of detail in the various objects, *e.g.* print and script, which have to be scrutinized, as well as upon the degree of contrast of these objects with their immediate background. These two factors are fundamental.

The size of critical detail was therefore measured, and contrast values assessed for a number of tasks representing typical office occupations, and in addition, measurements were recorded for some more specialized work undertaken in certain offices.

2. What really matters is the apparent size of detail, and this clearly depends not only on the actual dimensions of the object but also on its distance from the eyes. These two factors determine the angle which would be enclosed if lines were drawn from the boundaries of the object so as to converge to a point situated at the observing eye. This "visual angle" is directly proportional to the size of the actual image of the object formed in the viewer's eye, hence, the "fineness" of different kinds of work is best expressed numerically in terms of the angle subtended by the "critical" or "key" object detail at the point from which it is customary, or necessary, to view the work. When, for example, typewritten matter is viewed at ordinary reading distance, the detail upon which recognition of the different letters depends has an angular size of only a small fraction of a degree; for instance, "C" is only distinguished from "O" by a break in contour, and this gap subtends an angle at the eye of about 3 minutes.

The contrast which enables print or script to be distinguished from the paper or other material on which it occurs depends on a difference in reflection factors of print and paper. The conventional method of expressing contrast numerically is to express the difference of these two measured reflection factors—*e.g.* those of print and paper—as a percentage of the higher of the two factors. This is the method adopted here and, for example, the difference between the average value found for the reflection factor of typed characters and the average value found for typing papers is numerically equal to about 60 per cent of the paper reflection factor.

3. The measurements summarized in this Appendix relate to the reading of shorthand and typewritten notes, typewriter keys, telephone directories, stencils, and newspapers. In the more specialized sections are included Income Tax Tables, Mathematical Tables, Accounting and Order Machine Forms, Stock Exchange Lists, and Railway Timetables.

The numerals and letters selected for measurement were 3, 5, 6, 9, i, c, e, as it seems that these are more readily subject to confusion with others of similar form.

The "gaps" in the letters or numerals were measured by means of a travelling microscope.

Photographically prepared slips of known reflection factors were used to measure the contrast between the letters of numerals and their backgrounds.

The *visual angle* was calculated on the basis of a viewing distance of 13 in., *i.e.* ordinary reading distance.

In the case of drawing office work, the critical detail was considered to be the intersection of centre lines and the important contrasts, those between fairly hard pencil lines and ordinary drawing paper, those between pencil lines as seen through tracing paper and the tracing paper itself, and the corresponding contrast when tracing cloth is used.

Table 1*

WORK	SIZE						CONTRASTS		
	VISUAL ANGLE WITH VIEWING DISTANCE = 13 in.						GOOD ABOVE 60%	MEDIUM 60% to 30%	POOR BELOW 30%
	ABOVE 5′	5′–4′	4′–3′	3′–2′	2′–1′	BELOW 1′			
Typewritten Characters									
Average width of limb				*			*		
Gap in c				*			*		
Gap between "dot" and "i"					*		*		
Gap in 5			*				*		
Gap in 3			*				*		
"Carbon" copy (average)							*		
Typewriter Keys									
Average width of limb of letter	*						*		
Average width of line of numeral		*					*		
Income Tax Tables									
Gap in 9 and 6			*				*		
Gap in 3					*		*		
Gap in lower part of 5	*						*		
Gap in upper part of 5	*						*		
Shorthand Notes (Pencil)									
"Thick" strokes							*		
"Thin" strokes								*	
Telephone Directory									
Gap in c				*			*		
Gap in e					*		*		
Numerals (as Tax Tables)							*		
Logarithm Tables									
Gap in 5						*	*		
Gap in 3				*			*		
Gap in 6 and 9						*	*		
Stock Exchange Lists									
Gap in e (in fraction ⅜)				*			*		
Times Advertisements									
Gap in 5				*			*		
Gap in 3	*						*		
Gap in c			*				*		

* Results given in this Table for printed matter relate to the size and style of type used at the time of investigation in the publications mentioned.

TABLE 2*

WORK	SIZE						CONTRASTS		
	VISUAL ANGLE WITH VIEWING DISTANCE=13 in.						GOOD ABOVE 60%	MEDIUM 60% to 30%	POOR BELOW 30%
	ABOVE 5′	5′–4′	4′–3′	3′–2′	2′–1′	BELOW 1′			
Gestetner Sheet	*						*		
Accounting Machine Form									
Gap in 5	*						} *		
Gap in 3	*								
Order Machine Form									
Pale yellow copy	*						*		
Light blue copy	*							*	
Buff copy	*						*		
ABC Time Table									
Gap in 5				*			} *		
Gap in 3	*								
Gap in c			*						
Bradshaw					*		*		
Script (Blue Ink)							*		
Totals	11	1	5	7	4	2	16	2	
					2′–1′	BELOW 1′	GOOD ABOVE 60%	MEDIUM 60% TO 30%	POOR BELOW 30%
Drawing Offices Pencil lines on Drawing Paper Intersections					*			*	
ditto when covered with tracing paper					*				*
ditto when covered with tracing cloth					*				*

* Results given in this Table for printed matter relate to the size and style of type used at the time of investigation in the publications mentioned.

APPENDIX V

FLUORESCENT TUBULAR LAMPS

BY R. O. ACKERLEY, M.I.E.E., F.I.E.S.

1. Fluorescent lamps take the form of glass tubes in which light is generated from fluorescent powders coated on the inside of the tube and activated by the ultra-violet radiations from an electric discharge passing through mercury vapour at low pressure between electrodes at each end of the tubes.

The length of the tubes for general lighting purposes varies at the time of writing from 18″ up to 8′ 0″ or more, and the diameter from 1″ to 1½″. The special features in which they differ from incandescent light sources may be summarized as follows:

The large area of source due to their length induces very soft lighting free from harsh shadows. This characteristic makes them unsuitable for use where a highly concentrated directional beam of light is required, but such situations arise more frequently in special industrial applications, and for almost all office requirements this soft lighting is an advantage.

Their surface brightness is much lower than that of tungsten lamps; none the less, it is very desirable to have them shielded from direct view except when those lamps near the worker are mounted well above the normal line of vision.

The first fluorescent lamps were designed specifically for industrial use and gave a colour of light very close to natural daylight. Since then various warmer colours have been introduced under such names as "warm white," "natural," etc. The choice between them is largely a matter of individual taste, and many commercial users still prefer the "daylight" lamp.

2. The colour of the light from "white" fluorescent lamps is in general much closer to that of natural daylight than the light from incandescent lamps. The latter are generally very rich in the deeper red rays and their use has led to a preference towards very warm light for more social purposes such as lighting in the home, in restaurants, etc. The light from "white" fluorescent lamps consequently appears cold in comparison, but this is no disadvantage for working interiors where most of the present colours of "white" lamps have been proved satisfactory and also when artificial lighting has to be blended with natural lighting for many hours during the year. In a large office having windows on one side only, if fluorescent lamps are skilfully used on the side of the room away from the windows workers are largely unconscious of the fact that they are working by artificial light. There is, however, one point which should be noted about the use of fluorescent lamps emitting light of the colder colours. Unless ample illumination is provided, the interior is likely to appear dingy and this is probably due to an unconscious comparison with natural daylight under which illumination values are generally far greater. The use of insufficient artificial illumination has undoubtedly been the cause of many criticisms in the past. If illumination values such as those recommended in this Report are adopted, no fears need be entertained on this score.

It must also be recognized that while the daylight appearance of colours will be rather less distorted under the light of "white" fluorescent lamps than it is under other artificial light sources in general use, the distortion will have a different bias. Consequently wall colourings, for example, that may have appeared quite satisfactory under incandescent light, may not look so pleasing under the light of fluorescent lamps. As a case in point, under some of the "white" lamps, colours with a chrome base have proved unsatisfactory. It is wise therefore when using fluorescent lamps to choose for decoration colours which will respond pleasingly to the particular colour of light it is proposed to employ.

3. From the economic point of view, fluorescent lamps have an efficiency in terms of light given for power consumed of the order of 2 to 3 times that of tungsten incandescent lamps, and a life 2 to 3 times as long, varying according to the particular rating of the lamps used. The former figures are for average light output under service conditions throughout rated life as fluorescent lamps tend to drop in light output relatively rapidly during the first few hundred hours of life. This drop is taken into account in making the above comparison, and, in calculating illumination requirements, lighting engineers base their specifications on the average light throughout life which is now published by all the reputable makers of lamps.

4. However, there are certain disabilities associated with the operation of fluorescent lamps which partially offset these economic advantages. The first is that, unlike incandescent lamps, they will not work direct off the supply mains but need the interposition of appropriate control gear. Such gear usually includes a choke or similar device to limit the current, a starting device and equipment to improve the power factor and to suppress radio interference. The gear is usually housed in the fitting which holds the lamp but naturally adds materially to the capital cost of the installation.

5. Due to technical limitations it is also not at present possible to make fluorescent lamps of high wattage rating, the largest size at present available being the 8 ft. 125 watt lamp. Consequently, when high illumination values are required, a relatively large number of lamps have to be installed. In spite of these limitations, at the power rates generally prevailing for commercial premises, it will be found that an installation of fluorescent lamps, by saving in current, offsets substantially its maintenance and capital cost over a period of a few years, apart from the value of any improved quality of lighting that may result. The high lumen efficiency also makes it possible, by substituting fluorescent fittings, to increase materially the illumination provided by existing tungsten lighting installations without the necessity for new wiring to cope with an increased load.

6. The high efficiency also has an effect on the heat generated by a lighting installation. For equal total light output the heat to be disposed of is reduced in proportion to the reduced wattage and the ratio of radiant heat to convected heat is far less in fluorescent than in incandescent lamps. As a result of this the heat liable to be directed down on to a worker is only about a quarter of that from incandescent sources.

7. Some criticisms have been heard of the flicker apparent in the light from these lamps. Such flicker in general takes one of two forms. One is a flicker visible in the bare lamp near the two ends and this can be screened by appropriate covers or end caps. The other, due to the cyclic variation in the light arising from the A.C. supply, is usually most visible when rapidly moving or rotating objects are seen under the light. In practice, even in industrial interiors when such objects are frequently present, disability due to this flicker (known as stroboscopic) is rarely experienced and in office lighting it may almost be ignored. None the less, if its elimination is necessary this can be achieved by a simple method of wiring.

8. Another feature of the operation of fluorescent lamps is a hesitancy in starting due to the operation of the switch mechanism. The delay is less pronounced with the most modern types of gear and lamps than with those first marketed, but if desired, the starting can be made positive and instantaneous by fitting special gear at some increase in capital cost and loss of efficiency.

9. All the remarks made above apply particularly to those types of fluorescent lamps which operate at ordinary mains voltage, commonly referred to as hot cathode lamps. The majority of them are equally true of the cold cathode lamps which operate with the aid of transformers at relatively high voltages. The capital cost of an installation of cold cathode lamps is likely to be slightly higher, and the overall efficiency slightly lower than hot cathode lamps, but against this the life of the lamps is of the order of 10,000 hours and upwards. This long life may be a material advantage from the aspect of maintenance costs. Appropriate wiring regulations for the installation of such high voltage devices have recently been published by the I.E.E., and if these rules are followed no greater risk is involved in their use than in mains voltage types.

10. One other feature of the cold cathode lamps requires mention, namely, that lamps can be operated with a discharge through neon, thereby producing light very rich in the deeper red rays. The mixture of these lamps with the "white" lamps operated by the mercury discharge makes possible a combined light of

pleasing quality for situations where the white lamps alone might be considered too cold. Cold cathode lamps can also be supplied "tailor-made" to suit special architectural requirements.

11. The large-scale introduction of fluorescent lamps is relatively recent, and up to the end of the war they had hardly been used for purposes other than industrial lighting. The lamp used for this work was the familiar 5′ 0″ tube, but as with other new developments, improvements in technique are rapid, and in the few years since the war we have already seen not only the introduction of new ratings and colour, but also marked improvements in efficiency, life, light maintenance, and facility of operation. Further advances may be expected, but practical experience on a large scale both in this country and abroad, particularly in America, has proved that in their present state of development they provide an efficient means for office lighting that can hardly be ignored.

12. Finally, reference must be made to the health aspect of fluorescent lamps. The fact that their light is widely known as being generated by ultra-violet radiation, has led to a fear that rays dangerous to the eyes may emerge from them. In practice the glass envelope is completely opaque to all such harmful rays, and the lamps are no more injurious to the eyes of people working under them than tungsten filament, or gas lamps.

APPENDIX VI

AN EXAMPLE OF IMPROVEMENTS TO EXISTING OFFICES

INTRODUCTION

1. The conditions in which many civil servants work are unsatisfactory, as confirmed by the Inquiry, and the problem of providing improved conditions—modern offices and better furniture—has received much consideration during and since the war by the Treasury, the Ministry of Works, Study Groups, and Working Parties.

Recently, some demonstration offices have been completed at Ebury Bridge House; primarily to show in what manner the Ministry of Works are proceeding to solve the problem and to show what can be done in an existing building by new colour schemes and improved furniture and equipment; to show the results of preparatory work already completed; and to invite comments and suggestions which might be valuable in deciding future schemes and standards.

The rooms used for demonstration purposes were formerly decorated throughout in cream and green, which was one of the pre-war standard colour schemes. The photographs will give some idea of the layout and general appearance of the original state of the accommodation.

In the new colour schemes the aspect; the size and shape of the rooms; the amount of natural light each received and the nature of the occupation were all considered. The aim was to create with as few colours as possible a sense of spaciousness, a light and cheerful atmosphere, and suitably coloured backgrounds for the new and improved designs of furniture. Broadly speaking, bright, warm colours are used in sunless rooms and bright cool colours in the sunlit rooms. With the exception of a few rooms, such as the Drawing Office, Registry, Typing Pool, and First-Aid Room, where individual colour schemes were considered desirable, the rooms generally are treated in groups, each group having a colour scheme appropriate to aspect and occupation.

Light coloured carpets and linoleums were selected to harmonize with the colour schemes; metal cupboards, lockers, and filing cabinets were brought into colour harmony, and special consideration was given to the colour of the desk and table tops, the upholstery of the chairs, and such items as clocks and door furniture. Desks, tables, and book-cases throughout were of oak with a polished natural finish. A few pictures were selected and introduced as an added interest.

The completed scheme represented a useful example of what can be done with existing and often unsuitable office premises when the decorations, furniture, and fittings are all considered as a unified scheme. It demonstrates clearly many of the principles about light furniture and decorations and the use of colour we have discussed in our Report.

It is understood that reactions of staff will be ascertained at a later stage and that a full account of the experiment will be published elsewhere. In the meantime, through the courtesy of the Ministry of Works we are able to include the following account of measurements of the daylight factor taken by the Building Research Station in selected rooms before and after decoration.

MEASUREMENTS OF DAYLIGHT FACTOR MADE BEFORE AND AFTER RE-DECORATION

2. The daylight at a point in a room is usually measured in terms of a Daylight Factor, this being the ratio, expressed as a percentage, of the illumination at the point to that received out of doors from an unobstructed sky. (See also footnote to page 5.)

The indoor illumination comprises both direct and reflected daylight, the latter being dependent on the reflection factors of the interior surfaces (walls, ceiling, etc.) and, hence, on their state of decoration. It follows that the Daylight Factor is similarly dependent on the state of decoration of the room.

A study of the influence of the reflecting characteristics of walls and ceilings on the natural illumination in a building was made by Ives, Knowles, and Thompson.[1] They studied the effect of (a) white ceiling and walls, (b) black walls and white ceiling, and (c) black walls and ceilings. Consequently, it is necessary to interpolate between their values for conditions (a) and (c) in order to assess the effect of changes of reflection factor which result from normal redecorations. This process is not altogether satisfactory, and, in addition, no account of the effect of furnishings was taken in their studies; hence their data serves only as an approximate guide to the practical effect of redecoration in offices.

The preparation by the Ministry of Works of a number of demonstration offices at Ebury Bridge House provided an opportunity to measure the influence of redecoration on the daylight obtainable in these offices. In their original state these offices were representative of the condition at which redecoration would be considered necessary.

Daylight factors were measured at a number of selected points in each of four offices immediately prior to redecoration. At the same time the reflection factors of a considerable number of the surfaces in these rooms were measured.

ANALYSIS OF OBSERVATIONS

3. In Table 1 are shown daylight factors, both before and after redecoration, at each of the observation points in the four offices, together with the changes in daylight factor, and these changes expressed as percentages of the illumination obtained in the newly decorated offices.

Daylight factor contours of the offices are shown in Fig. 13, representing the offices before redecoration, and Fig. 14, representing the offices after redecoration. These contours are only approximate, since the offices were still in use when the first measurements were taken, making it impossible to locate the observation points at positions best suited for comprehensive surveys of the daylighting. However, the contours serve to illustrate the changed distributions and increases of daylighting due to redecoration.

[1] U.S. Treasury Department, Public Health Bulletin No. 218, April 1935.

Table 2 gives the reflection factors of principal surfaces in the offices before and after redecoration. The figures are the average of approximately 30 observations on each of the dirty surfaces and 10 observations on each of the redecorated surfaces.

Figure 15 is a histogram showing the frequency distribution of the changes in daylight factor on redecoration. It is seen that the largest number of observation points increased in daylight factor by 0·3–0·4 per cent. With a standard 500 f.c. sky this represents an increase in illumination of 1·5–2·0 lm./sq. ft.

Figure 16 shows an attempt to correlate percentage change in illumination with the distance of each observation point from the window wall. Although there is a wide scatter between the points, the regression line drawn through them shows that at points farther from the window the influence of the state of decoration of the room on the daylight obtainable is greater, as would of course be expected. At the back of these offices the decrease in illumination due to deterioration of the decorations is of the order of 50 per cent. This is equivalent to a 100 per cent increase in illumination at these positions on redecoration.

TABLE 1

OFFICE NO.	DAYLIGHT FACTOR: NEWLY DECORATED OFFICE	DAYLIGHT FACTOR: DIRTY OFFICE	CHANGE IN DAYLIGHT FACTOR	CHANGE EXPRESSED AS A PERCENTAGE DECREASE IN ILLUMINATION DUE TO DIRTYING	DEPTH IN FEET OF OBSERVATION POINT FROM WINDOW WALL
Old 203	6·2	4·2	2·0	32	3
New 207	1·9	1·6	0·3	18	7
	0·8	0·6	0·2	19	11
	2·4	1·6	0·8	30	2
	1·5	1·0	0·5	34	6
	0·9	0·5	0·4	42	10
	3·0	2·1	0·9	29	6
	1·2	0·9	0·3	25	9
	0·7	0·3	0·4	62	14
	0·8	0·5	0·3	39	12
	3·4	2·4	1·0	31	4
	0·7	0·3	0·4	60	15
Old 204	4·4	3·5	0·9	20	3
New 208	1·8	1·5	0·3	15	7
	0·7	0·5	0·2	27	11
	2·1	1·6	0·5	23	2
	1·6	1·1	0·5	31	6
	0·9	0·6	0·3	36	10
	0·8	0·4	0·4	44	12
Old 205	3·1	1·7	1·4	43	7
New 209	1·2	0·7	0·5	45	11
	1·0	0·6	0·4	43	13
	1·2	0·8	0·4	27	11
	1·2	0·8	0·4	38	11
Old 206	7·3	5·4	1·9	26	3
New 210	2·0	1·7	0·3	17	7
	1·0	0·6	0·4	37	12
	2·3	1·8	0·5	22	2
	1·5	0·8	0·7	45	6
	0·9	0·4	0·5	58	11
	1·4	0·8	0·6	41	9

Average decrease in illumination resulting from the deterioration in decoration =34 per cent

TABLE 2

SURFACE	REFLECTION FACTOR (%)	
	FRESHLY DECORATED	DIRTY
Ceilings	76	54
Walls	61	40
Friezes	61	34

The scatter of the observations about the regression line is due chiefly to the fact that, at any given point, the ratio of the light received by interreflections from the surfaces of walls, furniture, etc. to that received directly from the window will be influenced by the way in which the furnishings are disposed about the room. A test point close to a wall will be affected by a change in reflection factor of the wall to a greater degree than a test point close to a darker filing cabinet. In addition, there is necessarily some scatter of observations due to unavoidable changes in the distribution of sky brightness taking place during the course of a protracted series of photometric measurements. Whilst these measurements themselves have a probable error not greater than ± 10 per cent (the majority within ± 5 per cent) the daylight factor values (computed as the ratio of photometric measurements made inside the room to measurements of the sky conditions) may have a greater error for the above reason.

When these factors are properly taken into account, the effect of the redecoration of the rooms on the illumination level on the working plane is still seen to be clearly significant.

It is of interest also to compare the data obtained with values interpolated from the studies of Ives, Knowles, and Thompson referred to above. It is found that the agreement with corresponding points taken from the regression line of Fig. 16 is close. This is useful confirmation, suggesting that the regression line of Fig. 16 can be taken as an accurate indication of the effect of changes in the decorations of these particular offices.

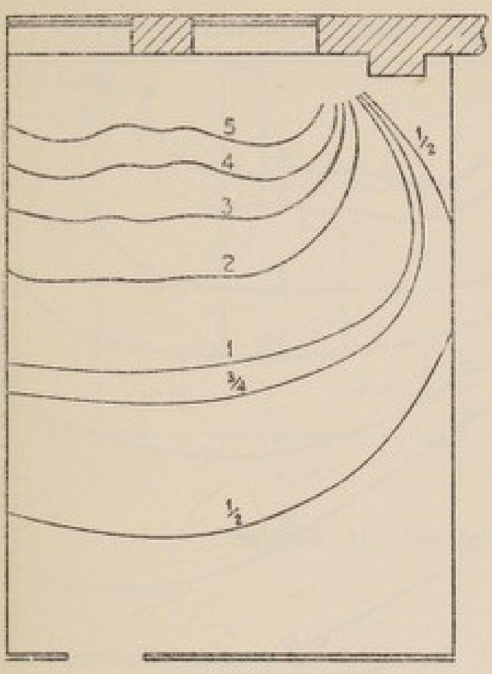
CONCLUSIONS

4. The investigation has shown that the state of decoration of this suite of offices has a measurable influence on the daylight obtainable.

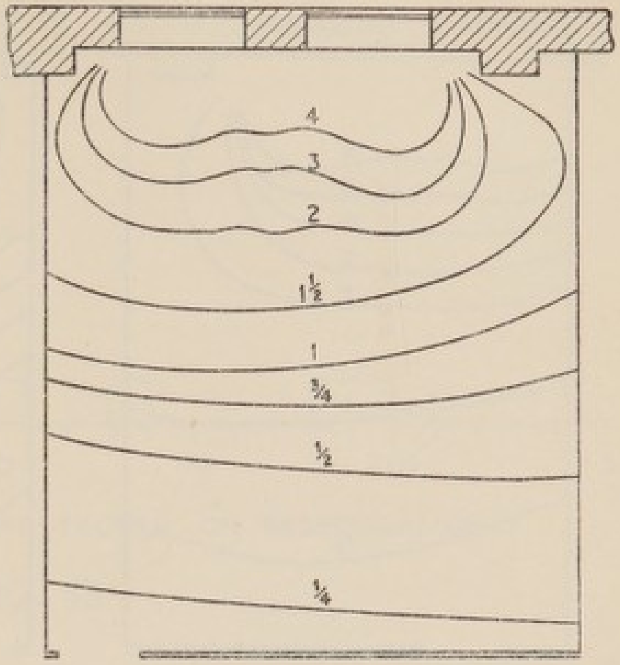
Increases in reflection factor of 22 per cent on the ceilings, of 21 per cent on the walls, and of 27 per cent of the friezes were responsible for average increases of daylight factor of about 0·35 per cent. This corresponds to the addition of 1·75 lm./sq. ft. to the interior illumination under the standard conditions of a 500 f.c. sky or to a 50 per cent increase in the average prevailing illumination.

An approximate correlation between percentage increase of daylight illumination and distance back from the window wall has been found. The effect of redecoration has been to double the illumination at the back of an office 16 feet deep where the daylight factor was 0·3 per cent under the deteriorated conditions, and to increase it by about 50 per cent at a point 8 feet from the window where the daylight factor was 1 per cent under the deteriorated conditions. Alternatively, the effect of deterioration of the decoration of the offices has been to decrease the illumination by about 50 per cent at the back, and by about 35 per cent at the 8 ft. point.

Rooms with better daylight penetration would, of course, have shown less effect with redecoration. This suite of offices is, however, fairly typical of Government and commercial office accommodation, so that the data are probably fairly representative.



ROOM NO. 207



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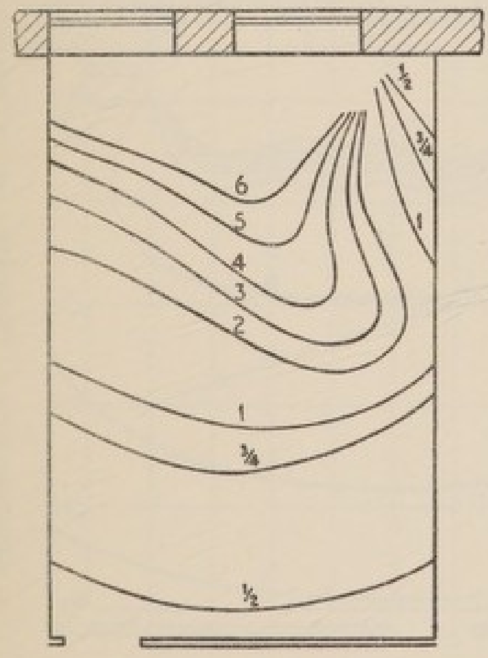

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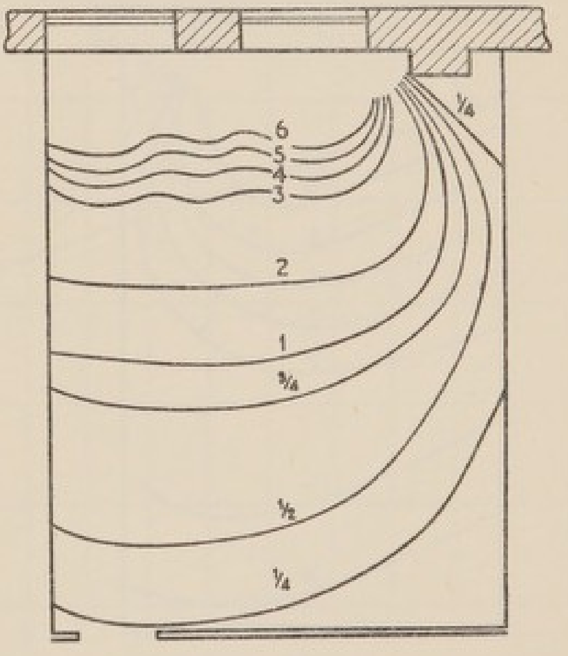


ROOM NO. 210

FIG. 13

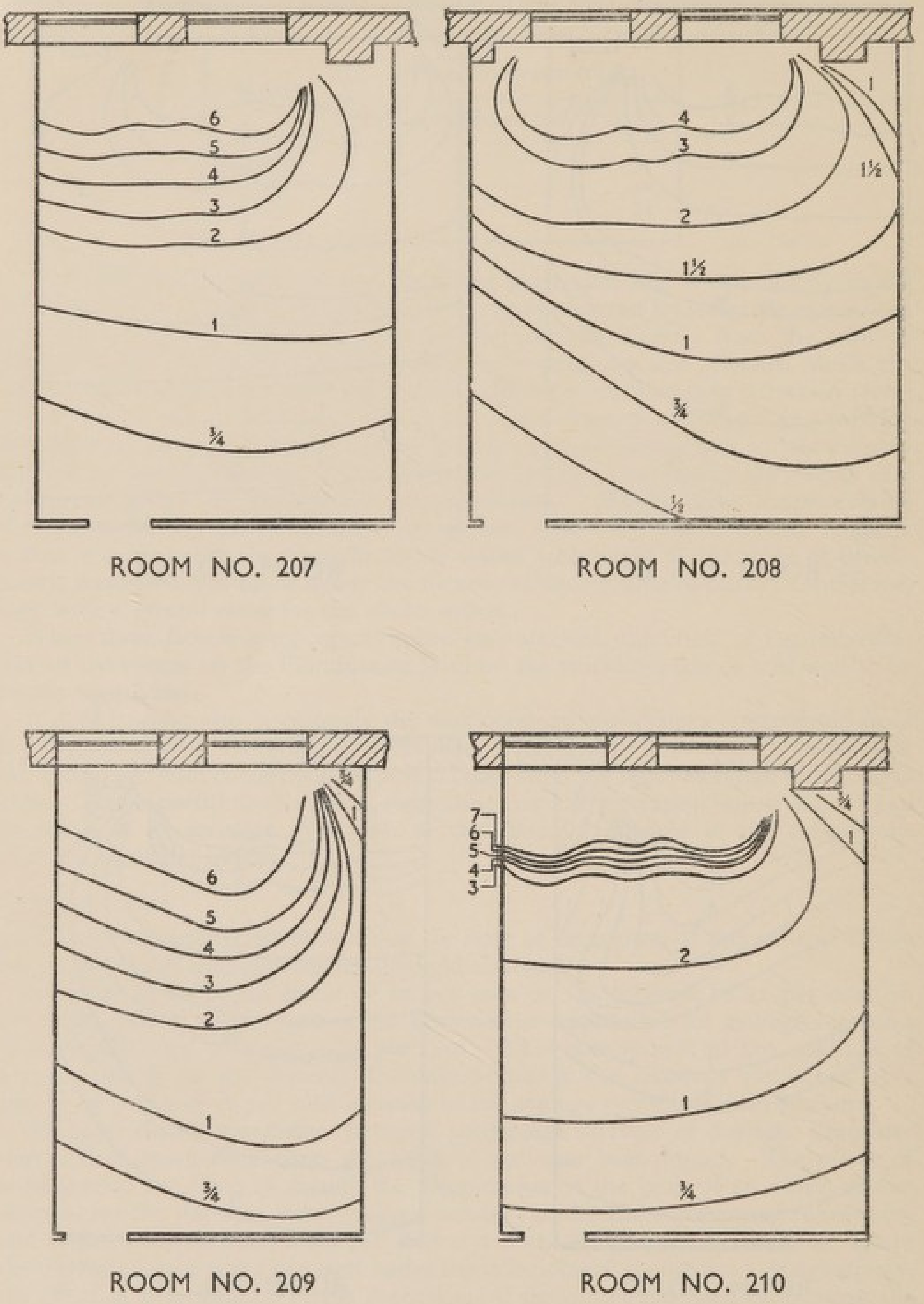
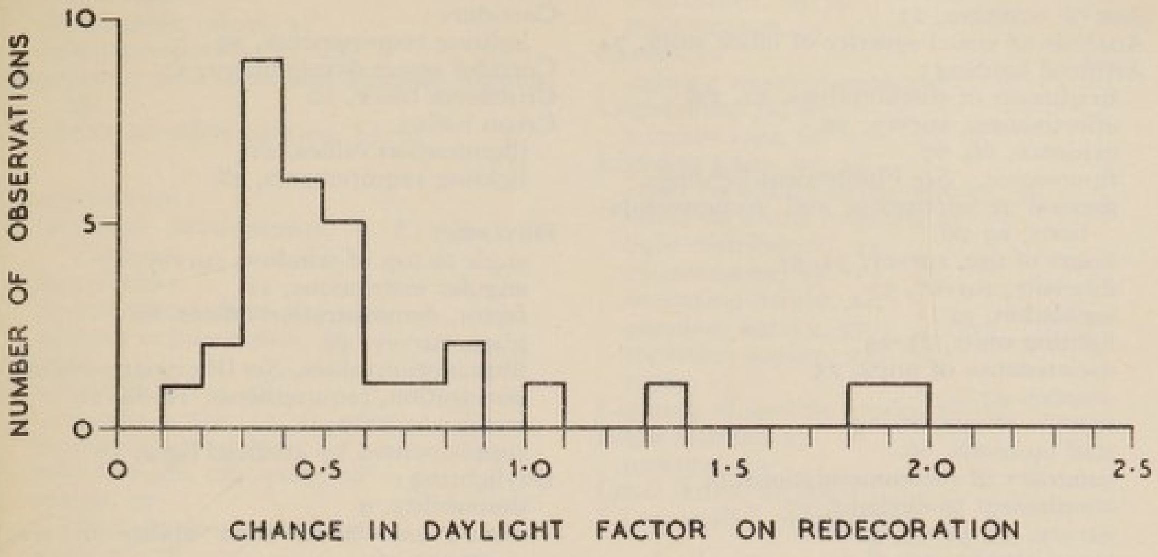
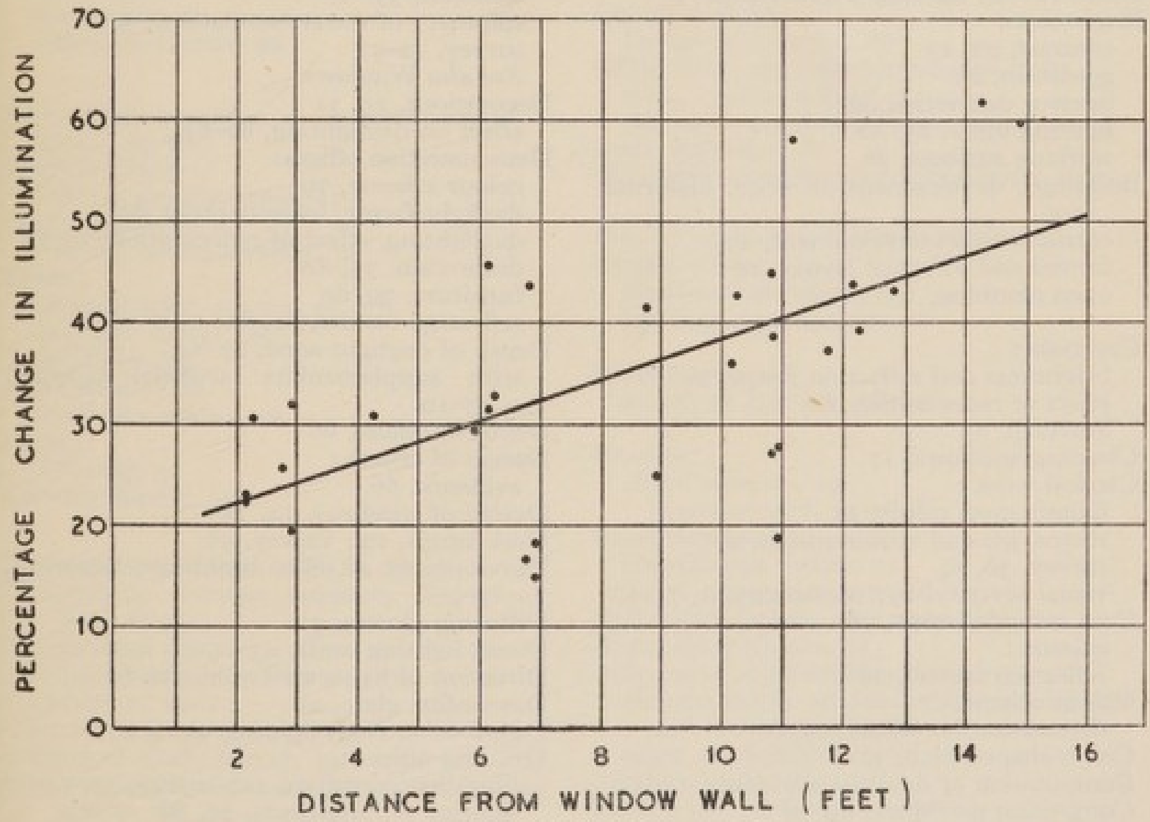


FIG. 14



NUMBER OF OBSERVATIONS
0
5
10
0
0·5
1·0
1·5
2·0
2·5
CHANGE IN DAYLIGHT FACTOR ON REDECORATION

FIG. 15



PERCENTAGE CHANGE IN ILLUMINATION
0
10
20
30
40
50
60
70
2
4
6
8
10
12
14
16
DISTANCE FROM WINDOW WALL (FEET)

FIG. 16

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25. HOUSE CONSTRUCTION. THIRD REPORT (see Nos. 1 and 23 above). 2*s.* (2*s.* 2*d.*)
26. DOMESTIC DRAINAGE. By the Plumbing Committee of the Building Research Board of the Department of Scientific and Industrial Research. 6*d.* (7½*d.*)
27. HEATING AND VENTILATION OF SCHOOLS. By the Heating and Ventilation (Reconstruction) Committee of the Building Research Board of the Department of Scientific and Industrial Research. 6*d.* (7½*d.*)
28. PRECAUTIONS AGAINST FIRE AND EXPLOSION IN UNDERGROUND CAR PARKS. By a Joint Committee of the Building Research Board of the Department of Scientific and Industrial Research, and of the Fire Offices' Committee. 1*s.* (1*s.* 2*d.*)

Prices in brackets include postage.

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