Artificial Daylight.

By Dr. L. C. MARTIN.

THE apparently simple question "What is Daylight?" raises at once a host of supplementary questions which are not easy to answer, and a little consideration shows that "daylight" is a word of somewhat indefinite meaning. The paper on which the present article is being written is illuminated by light from a north window. The sky is blue, but flecked with white clouds reflecting winter sunlight. A proportion of the light is, however, coming from the walls of an opposite house, and since this house is flanked by green trees and shrubs, they are also contributing their share of reflected light. A spectrophotometric examination of the light would doubtless reveal a somewhat irregular spectral distribution of energy, varying from minute to minute, although the eye registers no marked change in the appearance of the paper. Even after the drastic step of drawing the blinds and switching on the electric light, the appearance will scarcely indicate the tremendous alteration in the nature of the light, at any rate when the eye has been accustomed to the changed conditions. It is not until some effect of simultaneous contrast brings the artificial light into comparison with daylight that the difference between the two is revealed.

It is quite clear that it is useless to attempt to copy the heterogeneous radiation described above; therefore it is necessary to study the distribution of energy in the spectrum for summer sunlight and the light from a blue sky, and to see how far the means at present available will allow the production of radiation with similar characteristics. Some suitable compromise can then be decided upon. Fig. 1 shows, reduced to a common ordinate at $0{\cdot}59\mu$, the *relative* distribution of energy in the spectrum for blue-sky light, summer sunlight, and electric light (gas-filled incandescent lamp). The gas-filled lamp radiates, as indicated by experiment, in a manner similar to a perfect radiator (the black body of the physicist) at a temperature of 2800° C. By extrapolating from experimental results, it is found that the sun radiates like a perfect radiator at about 5000° C., a temperature unfortunately quite unattainable at present in any usual and practical terrestrial source of light. It is only in intense electric discharges that such temperatures can be attained experimentally.

Amongst the special means of light production the Moore vacuum tube must be mentioned. The discharge from a small transformer passes through rarefied carbon dioxide at a pressure of about 0·1 mm., the tubes being of considerable length when used for industrial lighting. Luckiesh states that the light is a "good approximation to average daylight." Since the spectrum consists of bands, however, and is by no means continuous, this light is apt to prove untrustworthy for colour matching purposes, more especially in dealing with substances possessing bright narrow bands in the spectrum of their transmitted or reflected light.

Phosphorescence and allied effects are extremely efficient in regard to the energy required in producing a given amount of light, but under present conditions the utilisation of the phenomena for commercial light production is not practicable.

We turn, then, to consider the means of modifying the energy distribution in the spectra of ordinary sources, and before proceeding to the better known methods, two useful laboratory devices may be mentioned. Priest finds that by passing the light through a system of polarising prisms and quartz plates cut perpendicular to the axis, the spectrum of such a source as the gas-filled tungsten lamp can be modified to an equivalent of that from a black body radiating at 5000° C., and moreover, the apparent temperature of the equivalent radiator can be controlled over a wide range. The Arons chromoscope is convenient for the purpose. Another method of interest is the spectrum template of Abney and Ives, in which the radiation from the source is first dispersed

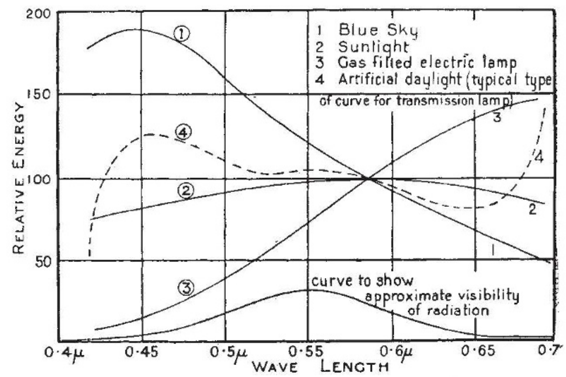


FIG. 1.—Relative distribution of energy in spectra of light sources.

into a spectrum and then recombined. In the plane of the spectrum a sector rotates, and one of the lines bounding the angular opening of the sector is curved in such a way that the effective angular aperture varies so as to be greatest in the blue and least in the red regions of the spectrum. In fact the apparent energy distribution in the spectrum of the reconstituted light can be made to follow any prescribed law.

It will be apparent, however, that the two foregoing methods are wasteful in so far as their action depends on the mere elimination of the excess energy of the longer wave-lengths.

Apart from consideration of energy distribution, however, the two methods above are quite impossible for lighting purposes, and therefore the aid of selectively transmitting or reflecting light filters or reflectors has to be employed, this expedient being suggested by Mr. A. P. Trotter some thirty years ago or so. In 1899 Dufton and Gardner produced a filter for correcting the light from the carbon arc. Though this light has an energy distribution which comes almost as near to sunlight as any artificial light (the temperature of the carbon arc is 3500° C. to 4000° C.), the flame of the arc gives an excess of violet radiation from the well-known cyanogen bands, and hence the radiation needs a special type of correction. Dufton and Gardner's glass was coloured blue-green by means of copper, and a trace of uranium gave the property of filtering out the excess of violet from the arc-light.

Since that time several types of colour filter made of special glass, or glass in series with dyed gelatin films, have been introduced for the correction of the light from other artificial sources, namely, ordinary metal filament electric lamps, gas-filled electric lamps, and incandescent gas lamps. Lamps employing coloured reflectors have also been introduced. The gas-filled electric lamps work at a higher temperature than those of the ordinary metal filament type, and consequently the correction required to produce artificial sunlight is less drastic in the first case. The correction for an incandescent gas mantle is even less since the spectrum of the radiation is particularly rich in the shorter wavelengths as compared with the radiation from a "black body" at the same temperature.

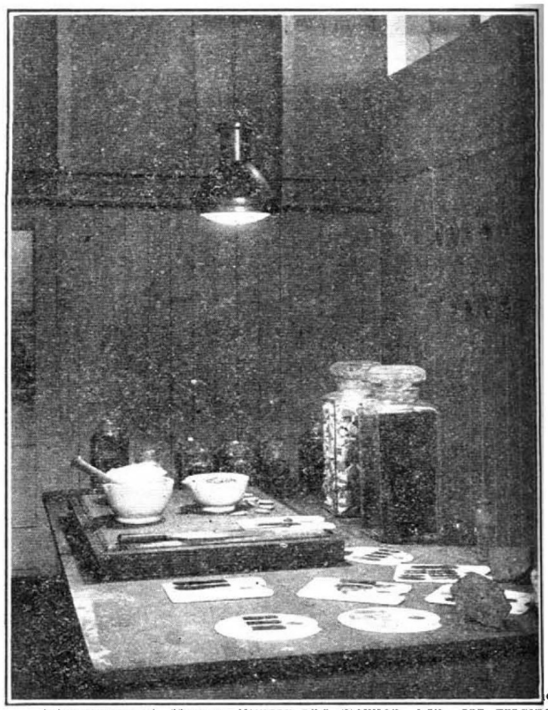
On the whole, experience has shown that the gas-filled lamp lends itself most readily to the present purpose, and practically all the modern lamps start with this light mainly because gas-filled lamps can be readily fitted into a lantern or shade without the greater difficulties of ventilation encountered when using an arc or gas burner.

There are at present several varieties of artificial daylight lamps on the market. In the first type the lamp is enclosed in a lantern with a reflector, and the light passes through a colour filter, the glass being coloured by various proportions of cobalt, manganese, nickel, and copper. Suitable glasses have been produced by Ives and Brady, and by Gaze in America. Messrs. Chance Brothers of Birmingham have also produced a "Daylight" glass. The type of correction usually aimed at is a compromise between the energy distribution found in sunlight and blue-sky light; thus the luminous efficiency of such units considered merely as sources of light is inevitably low. In one transmission lamp recently examined by the writer the overall efficiency was only 8 per cent. as compared with the unshaded lamp, but this was employing an ordinary metal filament bulb. If a gas-filled bulb had been employed the efficiency would probably have been much greater, perhaps 12-15 per cent.; a great deal depends on the reflector, which can, if well designed, produce a considerable concentration of light, thereby counteracting the unavoidable disadvantage of the loss of light in the filter.

The glasses employed for the filters often show some deviation from the desirable smooth transmission curve. In the unit due to Lamplough a small excess of green transmitted by one blue filter is compensated by the provision of a second filter of glass slightly coloured purple by the use of gold. The purple filter absorbs the excess of green and the quality of the light is greatly improved.

A second type of lamp (the Sheringham Daylight) employs the device of reflecting the light from a surface coloured with patches of blue, green, and red or yellow pigments in definite proportions of area. The light is completely diffused, and this is a considerable advantage when imitating the effects of actual daylight. Furthermore, the energy distribution of the reflected light can be made very "smooth," although it is difficult, just as before, to secure drastic correction without undue loss of energy. The method of making a spectro-photometric comparison between natural and artificial daylight has been described by Mr. P. R. Ord in the *Illuminating Engineer* for July 1923, but there is at present very little available information on the relative performances in energy distribution and luminous efficiency of the various lamps.

The actual correction attained in all these lamps is good over the brightest part of the visible spectrum between 0·45μ and 0·65μ. At the violet end the radiation is very deficient in violet, and at the extreme red end practically all the commercial units give far too much energy (see Fig. 1). The fact that these defects do not destroy the ordinary usefulness of the lamps is owing solely to the low visibility of the radiations corresponding to extreme ends of the spectrum, as shown by the lowest curve in Fig. 1. Occasionally the error is made manifest by some material with a low reflection through most of the spectrum and a large reflection at the red end. The "artificial daylight" may then produce a different appearance in such a substance as compared with daylight itself, but on the other hand, such materials vary greatly in appearance under the variations of daylight.



e laboratories of Messrs. Winsor and Newton, Ltd., for grading pigments. By courtesy of The Lamplough Daylamp, Ltd.

A third type of lamp usually employs a simple coloured bulb, either of coloured glass or coated with a gelatin filter. The correction in many of these units is not nearly so thorough, and therefore the luminous efficiency can be kept much higher, perhaps up to 60 per cent. or so. While lamps of this kind give a much better sense of relative value to blues and greens, they are of little use when exact colour matching is of importance, and recourse must therefore be made to the more fully corrected units.

Other types of lamp, of Continental origin, employ two or more colour filters. The light transmitted through these filters is mixed by diffusion.

In considering the spheres of usefulness of such lamps as are at present available, we recall first of all the considerable number of industries in which "grading" and estimations of quality of products by visual appearance are of the greatest importance. Tea, leather, tobacco, seeds, flour, and many other materials are all judged by colour, and until the modern daylight lamps were available a very great deal of time was lost owing to the lack of good daylight often experienced during the winter in industrial towns. So far as can be judged, however, artificial daylight has proved entirely satisfactory for purposes of this kind when sufficient care is employed in choosing a lamp suitable for the work in hand. A jeweller requires a strong light concentrated in a small area, and for this work one of the lamps with a focussing reflector would be best. On the other hand, for warehouse lighting a lamp giving good diffusion, such as the Sheringham Daylight, may prove the more suitable. The fully corrected lamps have been adapted for studio lighting by artists, and for counter illumination in drapers' shops and elsewhere. Fig. 2 shows a "Lamplough" transmission unit in use for grading pigments at Messrs. Winsor and Newton's.

Persons with experience of work with the artificial daylight units learn to adapt their estimations to the relatively constant light of these lamps, and less difficulty is often experienced than in working with highly variable daylight.

The "higher efficiency," and less fully corrected, lamps are applied with success for the lighting of shop windows by drapers and florists. A great improvement in colour values is secured without undue expense. The main factor militating against the employment of artificial daylight for general lighting seems to be a purely psychological one. Objection is taken to the "cold" appearance of the light when contrasted with that from ordinary lamps, but after all the matter is scarcely of importance if the corrected light is readily available when required.

It may be recalled that the difficulty of obtaining a reasonably constant standard of white light is one of the greatest difficulties in the application of colorimetry for modern industrial purposes. Stanford (*Biochemical Journal*, xvii. No. 6, 1923) has recently pointed out the usefulness of an artificial daylight lamp (the Sheringham lamp was actually used) for purposes of colorimetry with limited range colorimeters,[1] and for many chemical estimations, such as comparisons in Nessler cylinders. Artificial light corrected thus, or by a suitable filter of daylight glass, or by one of the laboratory methods described above, is of the greatest service in the more general problem of colour measurement which is being investigated with much energy in Germany and America at the present time, although the subject seems to attract little attention in Great Britain.

In conclusion, one might comment perhaps on the lack of interest shown by commercial firms in the subject of artificial daylight, and the improvement of lighting generally. In 1920 there were 15,000 fully corrected artificial daylight lamps in use in America, and the demand was then rapidly growing. In Great Britain it is doubtful whether a tenth of the American demand has been reached. The saving of time effected by the employment of such lamps in bad weather is so great that this indifference seems extraordinary, and the sooner this state of affairs is remedied the better for those industries to which this subject is of importance.

[1] See "Colour and Methods of Colour Reproduction" (Blackie), p. 114.

The Plant Commonwealth and its Mode of Government.[1]

By Sir FREDERICK KEEBLE, C.B.E., F.R.S.

TO describe in any detail the different kinds of receptor, or receiving apparatus, whereby an external stimulus of light, gravity, etc., is registered by the plant, lies beyond the purpose of this discourse. It is, however, essential to that purpose to point out that the region of reception of the stimulus is often separated by some distance from the region of reaction. Cut or burn the root of a sensitive plant, and presently the leaves begin to move. First, those nearest to the base of the stem bend down hingewise on the leaf cushion (pulvinus) and their leaflets fold together; then in succession those higher up the stem undergo a like series of changes, until all have soon reacted to the shock. Place a root on its side and its growing region an inch or so behind the tip, elongating more on the upper than on the lower side, initiates a curvature which continues until the tip points again vertically downward. But if, as Darwin showed, the tip be cut off before the root is placed in a horizontal position, no curvature occurs until a new root-tip has been regenerated. In the intervening days the root continues to grow horizontally. Cover or cut off the tip of the first leaf of a grass seedling and the actively elongating region fails to respond by curvature to one-sided illumination.

It is therefore evident that there is often a definite separation of receptor and effector region, and one of the most interesting problems in plant physiology is to discover how that gap is bridged. In animals nerves serve to connect the receptor organs—the receivers of specific stimuli—and the effector organs—the structures which respond by movement or other definite changes. But though many have sought for and some have thought to find them, those specialised conductors of excitation which are called nerves appear to be absent altogether from plants. Some have believed that the intercellular protoplasmic fibres serve like nerves to conduct impulses. It may be so, but facts are not very favourable to this interpretation of their function. It would, indeed, seem more probable that the protoplasmic intercellular strands serve to transmit not nervous impulses but materials from cell to cell.

There is, however, no need to carry these speculations further, since recent discoveries have thrown a new light and put a different complexion on the mode of transmission of excitation in plants. If a little mica plate be inserted into a cut made half way across the

[1] Continued from p. 15.