Introduction on Lighting

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The main object of lighting is seeing. The ability to visualize is especially essential in dealing with lighting problems in which the artistic aspect dominates and it must also be present in approaching any lighting problem. First, it is necessary to distinguish between illumination and brightness which are respectively cause and effect. It is important to acquire knowledge of optical laws, lighting effects, optical characteristic of surfaces, effect of surroundings, etc. or in other words to develop the ability to visualize the eventual results. Added to these is the knowledge of the fundamentals of lighting which are light, shade, and colour effects, and variations. Thus imagination and knowledge of the scientific and artistic aspects of lighting is the combination which results in a creative lighting. Variety also plays an important part in lighting since it is one of the vital necessities for human endurance and even for existence as it provides perpetual interest and alterations to suit our mood or fancy.

I — Light Sources

One of the first steps in designing a lighting installation is to decide on the kind of lamp. The primary purpose of a light source is the production of light, and the efficiency with which a lamp fulfills this purpose is expressed in terms of lumens emitted per watt of power consumed. If a source could be developed that would radiate all the energy it received as monochromatic yellow-green light in the region of maximum sensitivity of the eye, 550 Angstroms, it would produce approximately 680 lumens for each watt of power consumed.

At present, the designer has a choice of three main types of artificial sources:-

(a) Incandescent lamps
(b) Fluorescent lamps
(c) Mercury lamps.

The choice may be dictated by economic factors or may be influenced by colour, radiant heating, and other characteristics. In any case, the designer must be familiar with various lamps and their behaviour.

An important characteristics of a lamp is its efficiency or its lumen output per imput watt.

It is found in practice that, for a given life, a large lamp can be made with higher lumen output than a small lamp. A plot of lumens/watt against watts for commercially available lamps with 1000-hour life is shown in figure 1.

The lumen-output is also affected by the voltage for which the lamp is designed, a short thick filament giving better lamp than a long thin filament. Thus an automobile headlamp designed for 6 volts has a higher lumen ouput than a lamp of the same power designed for operation at 120 volts.

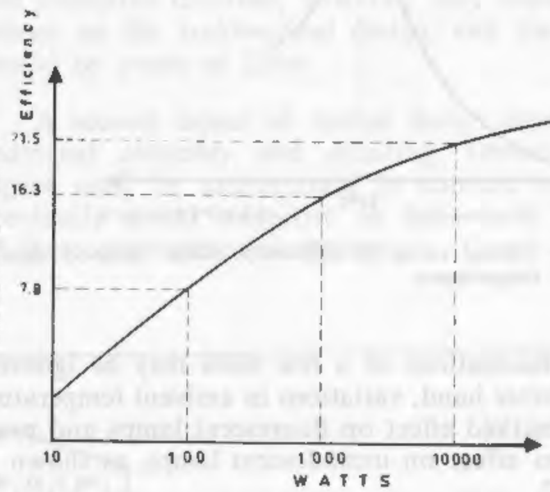

Fig. 1 — *Graph of Lumens/watt against watts*

The Effect of Voltage

The incandescent lamp is very sensitive to voltage changes. A one-volt change in the voltage applied to the lamp has a marked effect on both the lumen output and the life. As a general rule, lamps should be burned at rated voltage. Overvoltage operation results in higher wattage, higher efficiency, and higher light output, but shorter lamp life. Undervoltage burning while increasing lamp life, causes reduction in wattage, efficiency, and light output. A voltage as little as 5% below normal results in a loss of light amounting to more than 16%, with a saving in wattage of only 8%.

Tests show that the lumen output from a gas-filled tungsten lamp varies with the voltage according to the following empirical relations:

$$F_e = F_o \left(\frac{V}{V_o}\right)^{3.38} \qquad (1)$$

where V = voltage applied to the lamp,
V_o = rated voltage,
F_e = lumen output at V,
F_o = rated lumens at V_o.

The same form of equation is found to apply to power input P, filament temperature T, and life L, i.e.

$$P = P_o \left(\frac{V}{V_o}\right)^{1.54} \qquad (2)$$

$$T = T_o \left(\frac{V}{V_o}\right)^{0.424} \qquad (3)$$

$$L = L_o \left(\frac{V}{V_o}\right)^{13.1} \qquad (4)$$

The effect of line voltage is much less on fluorescent lamps than on incandescent lamps; so in the design of a fluorescent lighting installations, ordinary voltage fluctuations of a few volts may be ignored. On the other hand, variations in ambient temperature have a marked effect on fluorescent lamps and practically no effect on incandescent lamps, as shown in Figure 2.

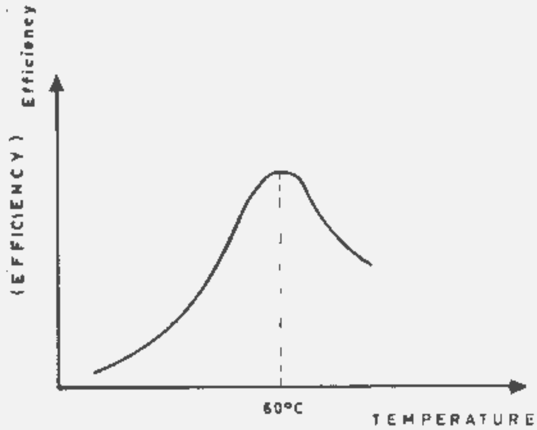

Fig. 2 — *Typical curve of efficiency (amp. tempe.) against temperuture*

One sees immediately why the fluorescent lamp has not yet revolutionized outdoor lighting in cold climates. Of even greater practical importance is the drop in lumen output at higher temperatures.

High Frequency Operation

The electric power industry was developed primarily to supply electric light by means of incandescent lamps. Thus, it is only natural that the standardization of frequency and voltage should have been strongly influenced by the characteristics of incandescent lamps. If frequency is reduced much below 50 c/s, incandescent lamps tend to flicker. At 25 c/s for instance, flicker may be quite annoying. On the other hand, the early A.C. motors were most satisfactory at low frequencies. A compromise was reached at 50 or 60 c/s. Voltage standardization at approximately 120 and 220V was a compromise between the high efficiency obtained with low voltage lamps, and the low line losses associated with high voltage.

The advent of the fluorescent lamp changed the whole picture. Tests show that fluorescent lamps operate better as the frequency rises. Figure 3 indicates how the efficiency rises as frequency increases.

As frequency increases life also increases, and flicker and stroboscopic effects disappear; also ballasts become smaller and less expensive. Thus the present standard frequency and voltage are not ideal for fluorescent lamps. Therefore, for best results, the frequency should be raised to several thousand c/s and the line voltage should be raised to at least 230V. Of course, no general change in the frequency of a country's supply system is feasible. But factories that generate their own electric power could very well employ a frequency such as 3000 c/s Generators are available up to 10,000 c/s. Even if electric energy is bought from power company, a motor-generator set can be employed to supply high frequency for lighting. With a large factory or office building, the cost of the frequency-converter might be more than compensated for by the lower cost of ballasts and by the improved performance of the lamps. The question of optimum frequency and voltage should be given careful consideration in the design of a large lighting installation.

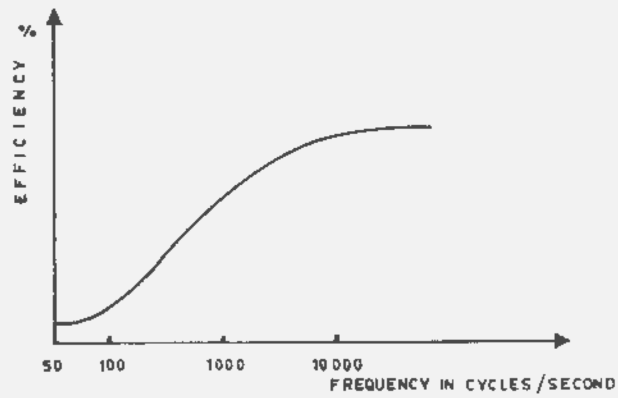

Fig. 3 — *Efficiency in % against frequency*

II — Lighting Design: Lighting and Architecture

The design of any lighting installation involves the consideration of many variables. What is the purpose of installation — is it light for critical seeing, light for selling, or light for decoration? How severe is the task of seeing, and for what length of time is it to be performed? What are the architectural and decorative requirements, together with constructural limitations of the area? What economic considerations are involved? The answers to questions such as these determine the amount of light that should be provided, and the best means of providing it. Eventually, the illuminating engineer may consider lighting design from three basic aspects: quantity, quality, and cost. Each one of these aspects merits very careful consideration by the designer.

Architectural considerations must be given due respect since it is a fallacy to consider lighting in terms of fixtures or proper distribution of light alone. The relation between lighting and architecture is of interest from several viewpoints. During the designing of a building a general idea of the lighting plan should be determined so that the necessary provisions may be made during the construction.

The lighting specialist should be able to suggest the placing of outlets, the types of units, the influence of the decorative scheme, the effect of light in modelling ornaments, and the general psychological and artistic effects of certain distributions of light, shade and color upon different details, areas, and the interior as a whole. There are, however, certain fields, such as industrial and office lighting in which the purely utilitarian and hygienic aspects are of chief or of sole importance. In such cases the illuminating engineer does excellent work and the architect may find plenty of expert assistance from the latter in solving the natural and artificial lighting problems. What is meant is that there must be, between an architect and illumination engineer, be a professional collaboration. It demands an endeavour to understand not only the underlying but olso the utmost convictions of the other professions and professionals engaged in the same project. It entails both giving and taking, but it does not allow for capriciousness nor uncompromising obstinacy. It obligates the illumination engineer to understand the aspects of architecture (which is not usually appreciated), but it also makes it incumbent upon tbe architect to realize that there are principles, laws, and a natural order of forces especially known to the engineer, with which no one indeed should attempt to compromise.

i However, it must be realized that there is an ncreasing gap between "total lighting objectives" on the one hand, and "precise lighting design" technique to implement these objectives on the other. This gap must be filled by applying empirical knowledge and experience, although this is often not a completely satisfactory answer. An initial need in lighting education, then, is the development of more adequate techniques for pre-determining the environmental effects of lighting in a space.

In the absence of such techniques, however, and in an attempt to cope with the changing emphasis toward environmental influences, lighting education has, in recent years, become increasingly oriented toward the architectural student rather than the engineering student.

It becomes relevant, then, to search for an educational form or structure through which the architectural student can be led to understand the nature of the several aspects of system design. One aspect involves safety and operating subtleties, such as, component sizing and dimensioning, circuiting, system alternatives and regulation, energy distribution, etc. This tends to be engineering in scope and content. The discipline involved, however, may impose limitations on the architectural design, and the student should be aware of these.

A second aspect of system design involves coordinated assembly and detailing. Obviously this aspect must be architectural in context, as is the previously noted subjective or behavioral function of these environmental systems.

As a further complication, we note that electric lighting, air handling, heating and cooling, and sound control have, in the past, been treated as isolated individual areas for training and design determination. Electric Lighting is even treated independently of daylighting effects in a space.

And yet the architectural student must recognize that the occupant of a room doesn't measure or judge these things in isolation. He reacts to the total environment. He finds the environment pleasant, or it is uncomfortable; he is attracted to a space or he is repelled by it. The enjoyment of a space involves all of the senses, and if any one of them is troubled, the total attitude of the individual is adversely affected. So each of our recent environmental developments must be analysed in relation to the composite effect of the overall system.

Finally, the task of instruction in lighting is complicated by the rapid rate of technological development that may quickly outmode the student's training in specific details. For this reason, the scope of education must be kept generally broad. It is, therefore, suggested that the first objective should be to develop perspective in the student, and a positive attitude for professional judgement to reflect:

(1) An awareness of the fact that this technology constitutes one of the areas of discipline within which a design program must be developed (as distinguished from an attitude that lighting devices can be readily superimposed onto a finished design);

(2) An awareness of the vocabulary involved in lighting design and the ability to use that vocabulary to communicate ideas and performance standard;

(3) An awareness of the fact that the integrity of the architectural design requires that the architect work to produce a *total* building system that works with a sense of unity or functional purpose (as distinguished from the attitude that recent technical developments such as lighting and air conditioning permit the architect to work in a vacuum, and then turn the problem of occupant comfort over to an engineer).

But although specific details may tend to become obsolete due to rapid technological advances, a fair depth of technical knowledge is still required. It therefore becomes necessary to recognize that many architectural graduates may be called upon to assume direct responsibility for a broader portion of the total building program. Possibly including more detailed design, calculation, and specification of electrical and mechanical systems.