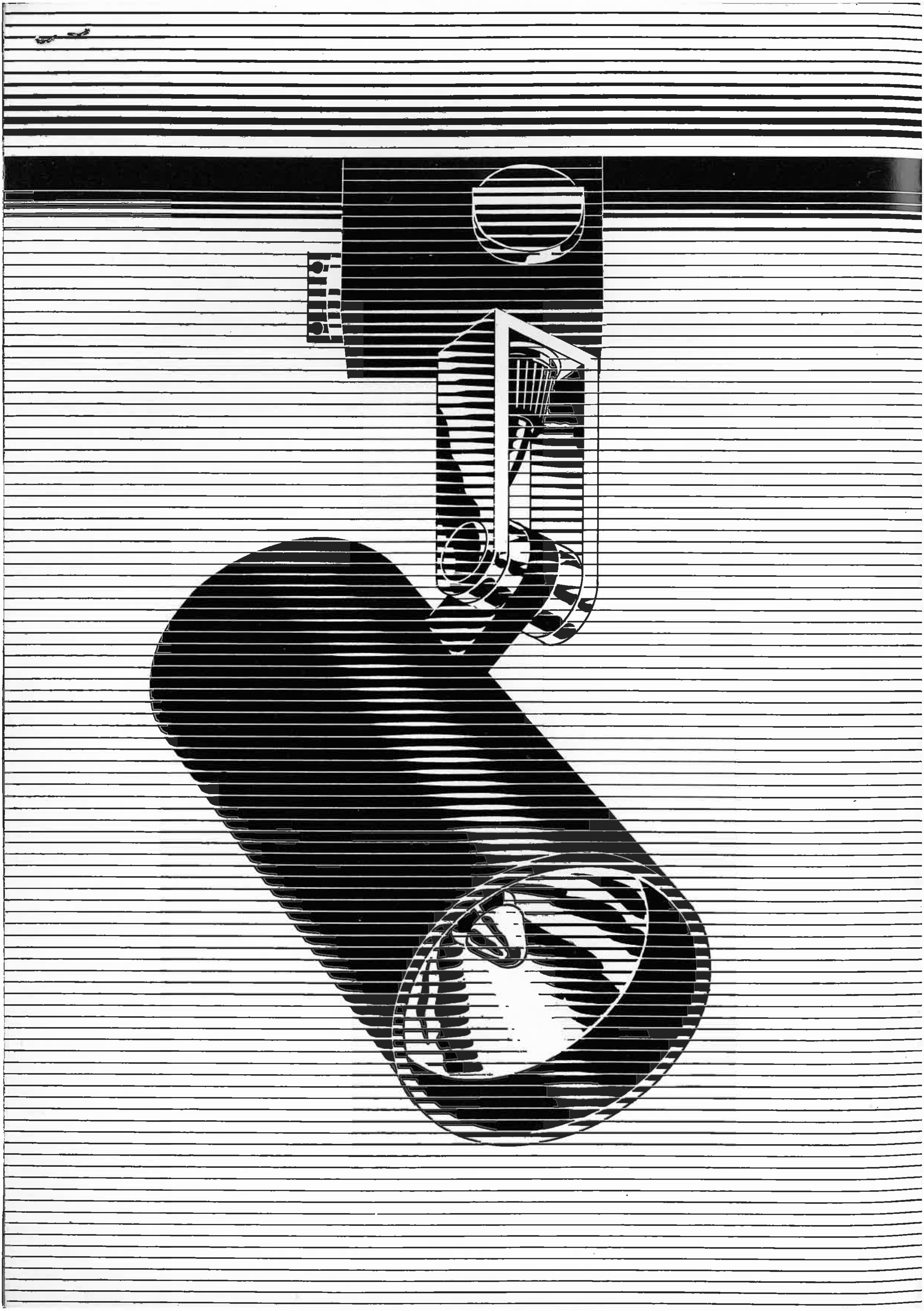
LIGHTING JOURNAL

Arena integrated ceiling system
colour and visual clarity
automobile auxiliary lamps

number eight/spring 1972/published by THORN LIGHTING LIMITED



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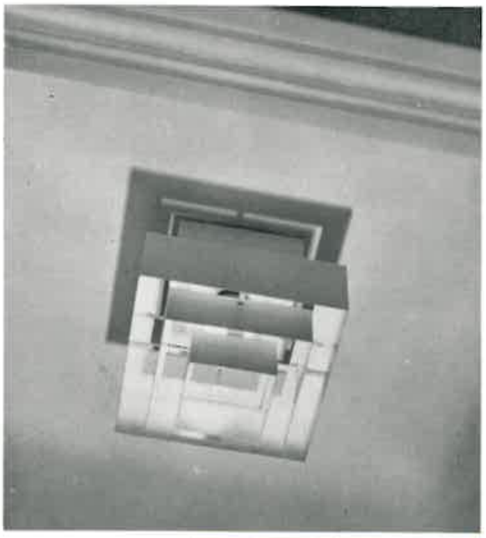
Cover picture shows Atlas Kolorlux lamps in a laboratory at Strathclyde University. The specially designed luminaire is seen below. Architects: Maurice & Steadman, Edinburgh; The Building Design Partnership.



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The effect produced by a great Gothic cathedral will vary very considerably according to the viewpoint of the observer. To one, the towering masses of the main façade may present a picture of barbaric majesty; to another, a glimpse of a turret or transept at the end of a street may give an impression of quaintness, or a view of a quiet cloister a feeling of repose. A third, seeing the building from an aircraft, may think that its most impressive feature is its complicated ground plan.

A company of the magnitude of Thorn Lighting poses a similar problem. This journal attempts to portray its activities, but because these are so diverse it is impossible to give a complete picture in a single issue—or, indeed, in several issues. Each article shows some aspect of the whole, depending on the position of the writer.

In this issue we present a profile of the company's managing director and look at some of the work done on fundamental problems of light and colour by the Lighting Research Laboratories at Leicester. There is a short description of the contribution made by some of the company's lighting experts to the International Illumination Congress (CIE) in Barcelona, and an article describing the development and application of new types of lamps for automobile indicator panels and ancillary lighting. Another writer explains the little known technique of producing light from photoconductors. These solid state lamps seem unimportant now but they have some interesting possibilities. The work and thought behind Arena, a new integrated ceiling system designed and marketed by the Isora Ceiling Division of Thorn Lighting, is described. This may well prove a turning point in integrated lighting design.

profile: A J Ford

One of the reasons for the success of Thorn Lighting is the very large proportion of board members with a technical background. Among them is the managing director, Mr A J Ford.

Born in North Kensington in 1911, Arthur John Ford was educated at Sloane School, Chelsea, and studied engineering at Acton Technical College and the Regent Street Polytechnic.

He started work in the valve-testing department of Marconi Osram Valves at Hammersmith, eventually becoming manufacturing manager. During the war his responsibilities increased, and he became manufacturing manager of all MOV's receiving valve production.

After the war he transferred to lamp manufacturing and became tube and lamp manufacturing manager of Osram GEC at Wembley, later taking over responsibility for the Team Valley lamp factory.

He joined Thorn in May 1949 as general manager, lamp production, and became a director of Atlas Lighting when that company was formed in 1957. He was responsible for organising the Thorn lamp factories in South Africa, Australia, New Zealand and Italy. Because of his earlier experience in valve manufacture Mr Ford was also responsible for integrating the Brimar Valve and Tube activities into the Thorn group. Later he performed the same service for the Mazda and Ediswan tubes operation. He was managing director of Thorn Radio Valves and Tubes from 1957 until January 1969 when he was appointed managing director of Thorn Lighting. Mr Ford is also a director of the parent company, Thorn Electrical Industries.

Mr Ford's recreations are reading, gardening and bridge. He is married, has a daughter and a son and lives at Northaw, Herts.

dans cette édition

in dieser ausgabe

2 KURZBIOGRAPHIE: A. J. Ford.
Ein Grund des Erfolges von Thorn Lightings ist die grosse Anzahl von leitenden Herren die eine umfangreiche technische Ausbildung haben. Zum Beispiel der Hauptdirektor Herr A. J. Ford.
In North Kensington in 1911 geboren A. J. Ford begann seine Laufbahn in der Röhrenprüfungsabteilung von Marconi Osram Valves in Hammersmith. Am ende war er Fabrikleiter geworden. Im Kriege vermehrten sich seine Verantwortlichkeiten und wurde Hauptfabrikleiter von M.O.V.
Nach dem Krieges ging er sich in die Lampenproduktion und wurde Lampenfabrikleiter von Osram GEC in Wembley.
In Mai 1949, schloss er sich Thorn als General Manager Lampenfabrik and und wurde Direktor von Atlas Lighting nach der Entstehung dieser Firma in 1957. Er organisierte die Thorn Lampenfabrikwerke in Süd Afrika, Australien, Neu Zealand und Italien. Nach seiner Arbeit als Geschäftsführender wurde er zum Hauptdirektor von Thorn Lighting in Januar 1969. Auch ist er Direktor von Thorn Electrical Industries, der Mutterfirma.
Herr Ford hat lesen, Gartenarbeit und Bridgespielen gern. Er ist verheiratet und hat einen Sohn und eine Tochter. Er wohnt in Northaw.

6 GALLIUM - ARSEN - PHOSPHOR - LAMPEN *von* **Dr. R. Hall, M.A. (Cantab), Ph.D., Leiter der Abteilung Elektroluminenz Lampen, Thorn Lighting, Leicester.**
Eine Halbleiter-Elektrolumineszenz-Diode ist eine Ausführung eines Gleichrichters mit lichtausstrahlender Eigenschaft. Sie beruht auf der Tatsache, daß ein Kristall bestehend aus zwei Schichten alliumarsen mit jeweils unterschiedlicher Verunreinigung bei Stromdurchgang eine elektromagnetische Strahlung emittiert. Ein solcher Kristall hat eine niedrige Impedanz in einer Richtung und eine hohe in der anderen Richtung, wobei die Strahlungsemission dann eintritt, wenn der Strom in Richtung der niedrigen Impedenz fließt; vor kurzem wurde durch den Zusatz von Phosphor eine Emission von sichtbarem Licht erreicht.
Der Kristall hat die Form eines Würfels von etwa 0,5 mm Kantenlänge mit der Elektrolumineszenz-Ubergangsstelle dicht an der oberen Fläche. Der elektrische Kontakt erfolgt über die gesamte Rückfläche und eine kleine Fläche in der Mitte der Oberseite für die Lichtemission. Das Licht wird durch die Verwendung einer rotgefärbten Epoxyd-Linse verstärkt, deren Brechungsindex etwa in der Mitte zwischen dem des Kristalles und der Raumluft liegt.
Wegen seines niedrigen Widerstandes in der Gegenrichtung kann die SSL nicht direkt mit einer Batterie betrieben werden, sondern der Strom muß durch einen Lastwiderstand begrenzt werden, der Teil eines Erkennungsnetzes zur Uberwachung von Maschinen bilden kann. Die Lichtleistung ist nahezu proportional dem Stromfluß über den normalen Arbeitsbereich, und die Betriebshelligkeit der Lampe liegt in der Größenordnung von 3000 cd/m², was für eine positive Erkennung selbst gegen einen gut beleuchteten Hintergrund ausreicht.
Die kleine physische Größe der Lichtquelle macht diese geeignet zur Verwendung auf gedruckten Schaltungen sowie als Miniatur-Anzeige; die Lebensdauer beträgt mehr als 100.000 Stunden, so daß die Lampe solange wie die Tafel hält, in der sie eingebaut ist. Ihre nichtlinearen Eigenschaften ermöglichen die Verwendung in sehr einfachen Schaltungen—oft ohne Verstärkung der Original-Signals.

9 ENTWURF EINES INTEGRIERTEN DECKEN-SYSTEMS *von* **R. C. Kember, B.Sc. (Hons) Eng., C.Eng., M.I.E.E., Hauptleiter, Isora Ceiling Division, Thorn Lighting Ltd.**
Enge Zusammenarbeit zwischen Architekten, Bau- und Beleuchtungsingenieuren, Heizungs- und Klimaingenieuren sowie Deckenherstellern ist eine wesentliche Voraussetzung bei der Konstruktion einer integrierten Umbebung, sie ist aber sehr schwer zu erzielen. Für eine einzelne Firma ist es nicht immer möglich, alle Versorgungseinrichtungen zu entwerfen und zu installieren, und nur wenige Firmen sind hierfür ausgerüstet.
Ein integriertes System, das alle Versorgungseinrichtungen im Baukastenprinzip bieten kann, ermöglicht größere Vielseitigkeit im Entwurf und spart Zeit und Geld bei der Installation; ein System dieser Art ist vor kurzem von Isora entwickelt worden.
Die schwersten Teile, die an der Decke aufzuhängen sind, sind die Beleuchtungskörper für Leuchtstoffröhren, die deshalb eine Einzelaufhängung an der Bauwerksplatte erfordern. Eine Einstellung dieser Elemente zur Anpassung an die Deckenkonstruktion kann schwierig und zeitraubend sein und eventuell Schäden an fertigen Decken verursachen. Die Grundidee des Arenasystems besteht darin, daß die Beleuchtungskörper die Hauptstütze für alle anderen Deckenelemente bilden und damit deren Lage bestimmen sollen.
Innerhalb der Thorn-Organisation wurde ein Team von Fachleuten zur Ausarbeitung dieser Idee gebildet, und das Ergebnis ist ein System, das auf einen Schlag das Hauptproblem der Befestigung der Beleuchtungskörper und die Koordination derselben mit der aufgehängten Decke löst. Besonders konstruierte Deckenfächer werden an einem Basisgitter aufgehöngt und enthalten alle Beleuchtungselemente sowie die mechanischen Teile für die Lüftungsanschlüsse. Sie werden so hergestellt, daß fast alle Arten von Deckenplatten angebracht werden können, und weil sie in einer vorher festgelegten Reihenfolge montiert werden müssen, klären sie die Abgrenzungen zwischen den betroffenen Installationsträger, wodurch Unklarheiten und Verzögerungen vermieden werden.
Ein wichtiger Teil bei dieser Arbeit war die Erstellung eines Handbuches mit ausführlichen Einzelheiten aller Bauteile sowie Installationshinweise. Die Zusammenstellung dieses Handbuches hat dazu beigetragen, die Ideen des Design-Teams zu klären. Es handelt sich hierbei um ein System, das den integrierten Umgebungsdesign wenn nicht leicht, so doch zumindestens weniger schwierig machen dürfte.

16 BELEUCHTUNG, FARBWIEDERGABE UND SICHTKLARHEIT *von* **H. E. Bellchambers, C.Eng., M.I.E.E., F.Illum.E.S., und A.C. Godby. Mr. Godby hat weitgehend an der in diesem Artikel von Mr. Bellchambers beschriebenen Arbeit mitgewirkt. Mr. Bellchambers ist Geschäftsführer des "Lighting Research Laboratory" in Leicester.**
Die spektralen Eigenschaften der Lichtquellen stehen in engem Zusammenhang mit deren Leistungsfähigkeiten. Lampen von hoher Leistungsfähigkeit haben ungenauere Farbwiedergabe-Eigenschaften, während diejenigen mit guter Farbwiedergabe eine niedrigere Leistungsfähigkeit aufweisen. Es ist eine allgemein gültige Feststellung, dass eine gut ausgeglichene Farbenfolge ansprechender ist, wenn sie von der zuletzt genannten Leuchtenart erfasst wird, und die Beobachtung hat gezeitigt, dass dies nicht nur lediglich auf die Farbwiedergabe von einzelnen Farbtönen zurückzuführen ist, sondern auf einen zusätzlichen Faktor, den man als "Sichtklarheit" bezeichnet.
Einige Beobachter berichten von einem Verschleierungseffekt, der auf farbigen Gegenständen festgestellt wird, wenn diese von Hochleistungslichtquellen beleuchtet werden, und der bei natürlichem Tageslicht unsichtbar ist.
In denjenigen Wellenbereichen, wo die Wahrnehmbarkeit des Auges geringer als der Maximalwert für Quellen mit einer gut ausgeglichenen Farbkraftverteilung ist, kann die Ausstrahlung gleich oder grösser als die Hochleistungsquellen sein, so dass die Scheinhelligkeit lichtreflektierender Flächen in diesen Wellenbereichen grösser ist als wenn dieselben unter letzteren Bedingungen gesehen werden.
In Leicester und anderswo ausgeführte Versuche haben diese Schlussfolgerungen erbracht. Die ersten beiden Serien bedienten sich zweier kleiner Gehäuse mit farbigen Gegenständen, von welchen der eine von einer Hochleistungslichtquelle und der andere von einer Quelle mit guter Farbwiedergabe beleuchtet wurden. Die Beleuchtung des zweiten Gehäuses unter sich der Kontrolle des Betrachters, und es wurde um eine berichtigte Einstellung gebeten, um eine gleiche Klarheit mit dem anderen zu verleihen, das der seinerseits auf 200, 400 und 800 lux eingestellt wurde.
Die Ergebnisse dieser Tests wurden in Frage gestellt, so dass sie zwecks Anwendung auf zwei identische Räume erweitert wurden, wobei die Betrachter in einer Position standen, wo sie beide gleichzeitig sehen konnten und die Beleuchtung wie zuvor variiert wurde. Die Ergebnisse beider Versuchsfolgen zeigen, dass bei subjektivem Vergleich °Kolorite- und andere Lampen mit tageslichtähnlichen Farbwiedergabeeigenschaften einen höheren Grad an Sichtklarheit ergeben als Lampen höherer Leistungsfähigkeit bei gleichen Beleuchtungswerten.

20 THORN LIGHTING UND DAS CIE *von* **W. K. Lumsden, Chefingenieur (Lichtung), Thorn Lighting Ltd.**
Der Internationale Ausschuß für Beleuchtung befasst sich mit der Erweiterung des Wissens von der Beleuchtung durch Fachausschüsse für den Ideenaustausch zwischen Beleuchtungsingenieuren der verschiedenen Länder sowie durch Unterstützung bei der Ausarbeitung internationaler Beleuchtungsnormen. Unterstützt wird der Ausschuß durch Beleuchtungsorganisationen überall in der Welt; alle vier Jahre wird eine Konferenz organisiert. Diese Konferenz fand im letzten Jahr in Barcelona statt.
Thorn Lighting spielt eine führende Rolle bei der Arbeit dieser Kommission, und eine Reihe Thorn-Mitarbeiter waren Mitglieder der britischen Delegation. Hierzu zählte Mr. Hewitt, dem Vorsitzenden des E3113, das sich mit den Umgebungsbedingungen befasst und dessen Sekretär der Verfasser dieses Artikels ist.
Dieser Ausschuß hat erhebliche Arbeiten auf dem Gebiet der Beurteilung von Beleuchtungsanlagen geleistet und ist dabei von den Regionalbüros von Thorn sowie von den Beleuchtungs-Entwicklungsgruppen in Enfield und Leicester unterstützt worden. Zusammenkünfte fanden 1969 in Paris und 1970 in Moskau statt. Auf der technischen Sitzung in Barcelona konnte, Mr. Hewitt diese Arbeiten erläutern, die beträchtliches internationales Interesse erweckten.
Die Barcelona-Konferenz wies eine Rekordteilnahme von mehr als 700 Delegierten auf. Arbeitssitzungen fanden für alle wichtigen Gebiete statt, unter anderem mit einem Vortrag von Harold Bellchambers, dessen Thema in einem Artikel dieser Zeitschrift behandelt wird. Die Konferenz wickelte eine enorme Arbeitsmenge ab, gleichzeitig fanden aber auch zahlreiche gesellschaftliche Veranstaltungen statt.

23 ENTWICKLUNGEN AUF DEM GEBIET DER KRAFTFAHRZEUG-HILFSBELEUCHTUNGEN
Der zweite Artikel von Mr. F. Woodward, C.Eng., M.I.Mech.E., Leiter der Glühlampen-technik Thorn Lighting, Leicester.
Den jüngsten Entwicklungen bei Kraftfahrzeug-Scheinwerfern ist viel Aufmerksamkeit gewidmet worden, weniger beachtet sind die Entwicklungen bei der Hilfsbeleuchtung von Fahrzeugen, die nichtsdestoweniger ihre Rolle bei der Senkung der Kosten und Verbesserung der Leistung spielen.
In den USA werden alle wichtigeren Bedienungselemente bald beleuchtet sein müssen, und es erscheint wahrscheinlich, daß diese Forderung letztlich auch bei uns hier von den Behörden vorgeschrieben wird. Dieser Prozess wird durch die Verwendung neuer Arten sockelfreier Lampen vereinfacht, die leicht in gedruckte Schaltungen eingesetzt werden können. Abgesehen von Lampe und Platte wird nur ein Teil benötigt, eine Federfassung, wodurch erhebliche Einsparungen bei der Montagezeit erreicht werden, da Löten, Verklemmen oder die Verwendung von aufschiebbaren elektrischen Anschlüssen entfallen.
Es gibt jetzt einige sehr kleine Lampen, die nicht nur bei Raummangel attraktiv sind, sondern auch die durch Erwärmung verursachten Schwierigkeiten verringern. Seiten- und Schlußleuchten werden ebenfalls in der Keilbasisform hergestellt, und ihre Anwendung für diesen Einsatzzweck nimmt zu.
Die neue Gesetzgebung, welche die Anbringung von Begrenzungslampen an grossen Fahrzeugen erforderlich macht, führte zur Entwicklung einer zweiteiligen Ausstattung mit roten und weissen Teilen (Profilen). Dies ist die erste eingebaute britische Anlage, bei welcher eine Langlebensleuchte in einem Plastikgehäuse eingebaut ist. Eine Fresnelische Vorderlinse bietet aufgrund einer 3 Watt-Leuchte mehr Licht als von vielen herkömmlichen 5 Watt-Begrenzungslampen. Leuchten mit grossen roten Linsen, die zusätzlich zu gesetzmässigen Schlusslichtleuchten verwendet werden, werden sich wahrscheinlich aufgrund von zahlreichen Zusammenstössen auf den Strassen einer grossen Beliebtheit erfreuen.

26 SELEKTIVE REFLEKTIONSSCHICHTEN *von* **W. J. McKlintic M.B.K.S. Leiter der Forschung Selektif Filters, Thorn Lighting, Leicester.**
Gewöhnliche Spiegel aus Glas oder Metall reflektieren den gesamten Bereich des sichtbaren Lichtes und ebenfalls ultrarote sowie ultraviolette Strahlung. Einige, wie z.B. Gold, reflektieren selektiv eine Farbe des Lichtes mehr als eine andere. Eine Untersuchung der Eigenschaften von Interferenzfiltern hat zur Herstellung einer Reihe sehr selektiver Spiegel geführt, sogenannte dichroitische Spiegel, deren Reflektionsvermögen für einige Bereiche des Spektrums sehr hoch, für andere wiederum sehr niedrig ist.
Das Prinzip eines Kaltlichtfilters beruht auf dem Verhalten von Lichtwellen beim Durchlaufen der Grenzfläche zwischen Materialien mit unterschiedlichen Brechungszahlen. Das von den Oberflächen reflektierte Licht ist um 180° zum einfallenden Licht phasenverschoben und je nachdem, ob der Brechungsindex des ersten Materials höher oder niedriger als der der zweiten Schicht ist, wird hierdurch das reflektierte Licht bei einer gegebenen Wellenlänge verstärkt oder verringert, die das Vierfache der Dicke des Materials sein muß. Alle anderen Wellenlängen werden durchgelassen.
Auf diese Weise können sehr wirkungsvolle selektive Reflektoren hergestellt werden, die entweder das Licht einer gegebenen Farbe reflektieren und die Komplementärfarbe durchlassen, oder durch Veränderung der Schichtdicken des Materials das Licht reflektieren, während die ultrarote oder ultraviolette Strahlung durchgelassen wird.

The Queen's Award to Industry

For the first time since its inauguration in 1966 the Queen's Award to Industry for Technical Innovation has been given to a lighting company. Thorn Lighting has received the Award for the following six innovations:

The development of bromophosphonitrile, known as the B1 additive. This material, added to the gas filling of the lamp, allows a closer control of the halogen "dose" than has been possible up to date and also, because of the presence of phosphorus, acts as a "getter," removing traces of water vapour and other impurities.

The introduction of 300W and 500W linear mains voltage lamps: these were the first tungsten-halogen lamps suitable for use on normal mains-voltage circuits.

The production of U-tube tungsten-halogen photoflood lamps: this is another "world first".

A 24V 250W cine projector lamp with a dichroic mirror. The dichroic mirror, the principle of which is described in an article in this issue, allows a remarkably high increase in screen brightness without overheating the film in the "gate" of the projector.

Miniature tungsten-halogen lamps, operating at six volts in 10 and 20W rating. An article in the last issue of the *Journal* described the use of these lamps for display purposes.

The development of a photo-etched molybdenum frame mount
This is an important feature of the H4 tungsten-halogen twin filament auto headlamp described in our last issue. Its use simplifies manufacture and allows extremely accurate location of the filament.
All these innovations were developed in Thorn Lighting's research and development laboratories at Enfield and Leicester, under the direction of Mr. A. H. Willoughby whose profile appeared in our last issue.

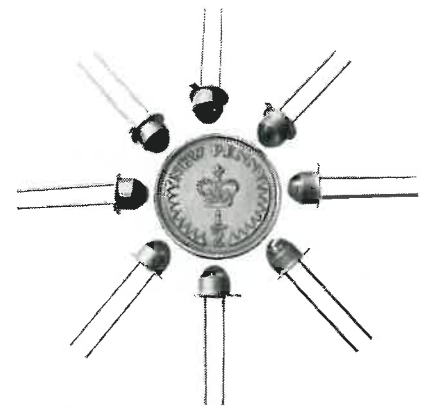
gallium arsenide phosphide lamps

by R Hall MA (Cantab) PhD

A semiconductor electroluminescent diode, as its name implies, is a form of rectifier which has the property of emitting light. The principle was established early in the century but was neglected until 1962, although a great deal of work was done on electroluminescent panels which work on a somewhat different principle. As explained in *Lighting Journal* no. 7 (X-Ray Image Storage Panels), these consist of a layer of phosphor sandwiched between two electrodes which emit light when an alternating electric field is applied. The principle of the solid state lamp (or SSL) is rather different.

The device is based on the observation that a crystal consisting of two layers of gallium arsenide, each containing a different type of impurity, emits electro-magnetic radiation when current is passed through it. The junction has a low impedance in one direction, while in the reverse direction only a small leakage current flows until the applied voltage reaches breakdown level and a current avalanche occurs. Its electrical characteristics are, in fact, very similar to those of a germanium or silicon rectifier diode. Recently it has been established that gallium arsenide phosphide can emit red, yellow or green radiation depending on the relative proportions of arsenic to phosphide and it is this type of crystal which is the heart of the solid state lamp.

The crystal takes the form of a dice, normally about 0.5 mm square, which contains the electroluminescent junction, usually referred to as the p-n junction. This junction is very close (5 microns) to and parallel with the top surface of the crystal (Figure 1). Electrical contact to the dice is made over the whole of the back face and to a small area placed in the centre of the upper face so as to obtain uniform illumination while obstructing as little light as possible. When made up into a lamp a red tinted transparent epoxy resin lens is applied to the front of the crystal which has already been mounted on a suitable base.



Solid state lamps: actual size

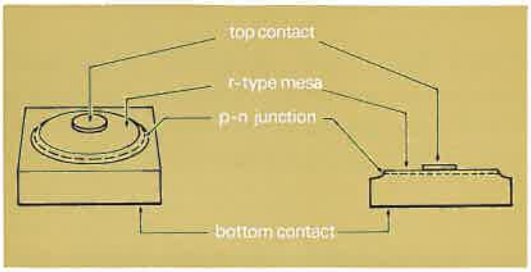


Figure 1 Basic construction of the crystal

Production of light

When an electron is injected from the n-type into the p-type material by applying a forward voltage, it loses its excess potential energy either by collision with lattice vibrations, giving rise to heating, or by emission of photons (light waves).

The electroluminescent p-n junction may, therefore, be described as one in which the electrons convert an appreciable fraction of their energy into electromagnetic radiation. For the application of semiconductor lamps interest is particularly directed to visible radiation.

Although one normally associates the colour of light with wave length, measured in nanometers, it can also be specified as energy measured in electron volts. For example, red light (approximately 720 nm) has an energy of 1.7 electron volts and green light 2.2 volts. These electron potentials are very close to the 'knee voltage' at which current begins to flow in the p-n junction.

Gallium arsenide phosphide material

Although the initial semiconductor material used for junction electroluminescence was gallium arsenide, this emitted only infra-red radiations. A companion semiconductor, gallium phosphide, was

Dr Hall is head of the Solid State Lamp Research Department of Thorn Lighting.

found to emit light but at a much lower efficiency. The obvious development was to make a compromise between the more efficient source and that which would emit light and this was done by replacing some of the arsenic atoms with phosphorus, producing a mixed compound semiconductor. Gallium arsenide phosphide gives maximum light output in the red region (650-670 nm).

Electrical characteristics

As previously stated, the solid state lamp is based on the operation of a p-n junction with electrical characteristics as shown by the solid line in Figure 2. It will be seen that in the forward (low impedance) direction the current rises slowly until a critical voltage Vk (the 'knee voltage') is reached, after which it increases rapidly. In the reverse direction a negligible leakage current flows until the applied voltage causes current avalanche at the reverse breakdown voltage.

Because of this characteristic the SSL cannot be operated directly from a battery but must have a ballast impedance which limits the current to the recommended operating value. Table 1 shows the values of resistance required for the Thorn SSL and the effect of this ballast on the characteristic curve is shown by the broken line in Figure 2. This is compared with those of an incandescent 5V 60 mA lamp which will be seen to be symmetrical about the origin.

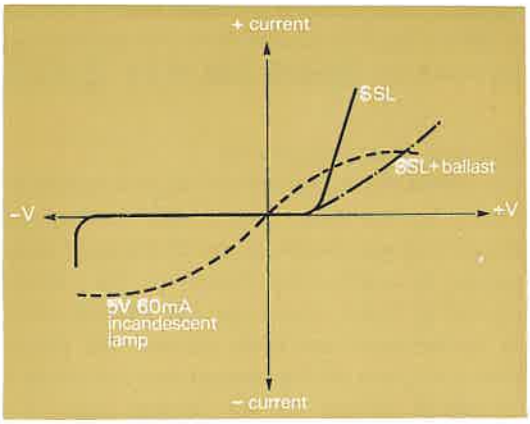


Figure 2 Electrical Characteristics

Supply voltage	Resistor
5V	56Ω $\frac{1}{4}$ watt
6V	68Ω $\frac{1}{4}$ watt
12V	180Ω 1 watt

Table 1

Construction

The heart of a semiconductor is the p-n junction. The basic material of which this is constructed is not of uniform composition because of the difficulty of growing such crystals. The technique adopted is to start with a wafer of single crystal gallium arsenide and then, by using a vapour phase reactor, to grow a crystal of gallium arsenide phosphide on to this susbtrate. To minimise dislocations the phosphorus content is only slowly increased to the desired value and then a constant composition layer is grown.

The original crystal contains impurities which result in it being n-type. The p-n junction is obtained by diffusing zinc into its surface at a temperature of approximately 800° C which reverses the balance and produces a thin film of the p-type material all over it. Because of the volatile nature of the phosphorus and arsenic the annealing is performed in a closed ampoule of quartz. After grinding the p-type material from the back face of the crystal, electrical contacts are evaporated to both faces. The rear face is completely covered by sequential layers of tin and gold and on the top face an array of gold crosses or dot contacts is made by using an in-contact mask.

The next step is to etch through the top p-surface to form an array of diodes concentric with the contacts already deposited. This is achieved by photolithographic techniques so that the centre contact and some of the surrounding material is left standing proud of the surface. This configuration is called a 'mesa', a term derived from the eroded tablelands of rock which are a well known feature of the desert of Mexico. The wafer is then scribed into individual dice with the mesaed junction at the centre. The semiconductor p-n diode is now completed and is ready to be mounted in a suitable housing.

The choice of housing depends on the requirements of heat dissipation from the diode (for the 60 mA device a suitable housing is the TO-18 header). The diode is mounted at the centre of the header by a low temperature eutectic bond which may be compared with a soldered joint. The top contact is then achieved by bonding a fine gold wire from the lead-through post to the evaporated contact on the chip. Finally a red tinted transparent epoxy is fixed over the chip and post, making the device very robust and shock resistant and increasing the light output from the chip. Because the refractive index of the epoxy is intermediate between that of the semiconductor and the air, it allows light to escape from the surface of the crystal which would otherwise be internally reflected and lost.

Optical characteristics

The luminous output of the high brightness Thorn SSL is shown in Figure 3. The solid line which corresponds to pulsed operation shows a linear dependence of the light output on current. The light output is nearly proportional to the current flow over the normal operating range. However, the heating effect of the forward current in continuous operation causes the junction temperature to rise above ambient with a consequent reduction in light output. The effect of this is shown by the broken line. To ensure long life and a light output drop not greater than 50%, the Thorn SSL should not be operated continuously at a junction temperature of above 100° C.
If the lamp is being driven from a battery with a current limiting resistor it shows considerably less variation of light output with voltage than a normal filament lamp (Figure 4). The operating brightness of the lamp is in the order of 34 000 cd/m² which is sufficient for positive identification even against a well lit background.

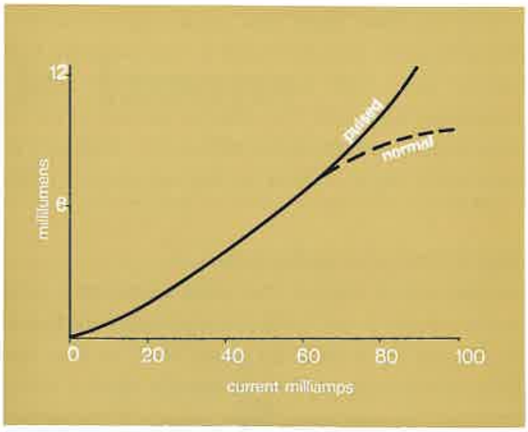


Figure 3 Optical characteristics

Life

An exponential decay of the light output throughout the life of the lamps results in eventual failure. For operation at room temperature a half-life of 100 000 hours has been extrapolated.

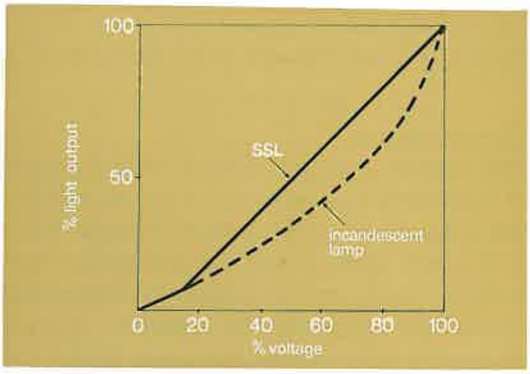


Figure 4 Variation of light output with voltage compared with an incandescent lamp.

Application

The semiconductor lamp, because of its approximately monochromatic emission, is suitable primarily as an indicator not as an illuminant (although possibilities of high powered lamps as dark room safe-lamps have been suggested).
When used in conjunction with a series resistor the lamp provides a long life, high brightness indicator which is capable of monitoring many physical phenomena. It is therefore likely to replace the short lived and less brilliant incandescent indicator lamps. The low voltage non-linear electrical characteristic of the SSL may allow them to be used directly in the transducer circuit, obviating the necessity for the amplifier and relay needed for incandescent lamps.
Such a typical simple circuit based on a Wheatstone bridge is shown in Figure 5. This is designed to be used as a temperature monitor.

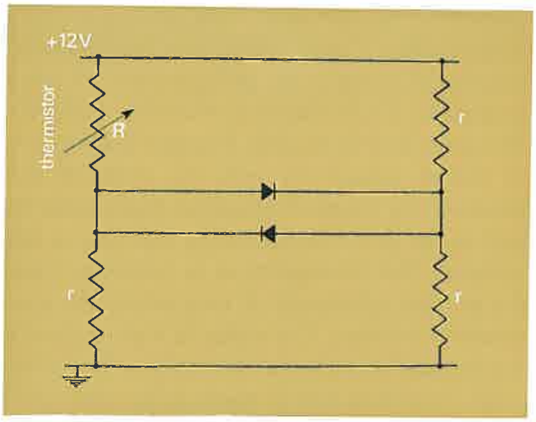


Figure 5 Typical Wheatstone bridge circuit.

Conclusion

There are three major points which make the semiconductor lamp more attractive than the conventional indicator lamp:
(i) **Size**: the small physical size of the light emitting area together with the fact that no filter is required offers the possibility of a compact structure suitable for use on printed circuit board and miniature displays.
(ii) **Long life and robustness**: one of the chief disadvantages of filament indicator lamps is their need for maintenance. It is envisaged that the semiconductor lamp would normally operate over the life of the equipment. A further consequence of long life would be the possibility of complete encapsulation in a display panel.
(iii) **Electrical characteristics**: although the electrical characteristic of the semiconductor lamp may, at first glance, be thought of as a disadvantage because it cannot be operated directly from a battery, in fact, the non-linear characteristic allows it to be used as a logic element in its own right, in many cases without amplification of the original signal.

the Arena integrated ceiling system

by R C Kember BSc(Hons)Eng CEng MIEE

The lighting engineer is no longer concerned solely with designing the best seeing conditions for the money available. Today he is expected to co-operate with architect, structural engineer, ceiling contractor and heating and ventilating engineer to provide a completely integrated environment.

To achieve such a synthesis is not easy and the need for cooperation must be fully appreciated. One method, described in the previous issue of *Lighting Journal*, is for a single firm to design and provide lighting, suspended ceilings and air conditioning plant, but this is not always practicable, nor indeed desirable. Furthermore, there are few companies equipped to perform such a service.

A different approach is to design an integrated system which can be adapted to provide lighting, suspended ceilings and air conditioning, if required, from a standard kit of parts. If the system is well thought out it can give considerable flexibility of design and at the same time effect a marked saving of time and money. Because the order of installation is dictated in advance by the system, it is possible to programme the work very accurately, avoiding the delays which occur when tradesmen are kept waiting for each other to finish. Because all the components are designed to be used together nothing has to be adapted on site, thus removing a common cause of delay and damage and making it possible to allocate clear responsibility to each contractor, thus avoiding erection problems and arguments about costs.

The Arena system recently developed by the Isora Division of Thorn Lighting is intended to fulfil these requirements, and it may be of some interest to consider the thinking which lay behind its design and some of the solutions to installation problems it provides.

The heaviest items to be hung on the ceiling are the fluorescent lighting fittings. These are too heavy to be supported by most lightweight frameworks for suspended ceilings so they are frequently hung independently from the structural slab. This means that fixings must be provided for the lighting fittings as well as for the ceiling supports, and that these fixings must be accurately positioned so that the lighting fittings eventually fit neatly into the openings provided for them in the ceiling. Very careful and coordinated setting-out is necessary and it is unusual to find that the ceiling tiles and lighting fittings marry up without adjustment being made at a late stage when this can waste time or cause damage. If the lighting fittings are installed first and the suspended ceiling put up afterwards, adjustments are hard enough to make, but the reverse process raises even more serious difficulties as the electricians must then work in the cavity between the suspended ceiling and the structural slab, which is awkward and inconvenient. If air conditioning is also provided, a further complication occurs. The positioning of ducting runs may conflict with that of the lighting fittings or may complicate their fixing or that of the suspended ceiling. The same difficulties of accurate location and connection apply to air supply and extract grilles.

The fundamental idea behind the Arena system is that the lighting fittings, the heaviest single item in the ceiling, should provide the main supports for the ceiling tiles and that their position should determine that of all other components. It is basically a suspension

R C Kember is General Manager of the Isora Division of Thorn Lighting.

First installation of the Arena system is in the London Electricity Board's new showroom at Poplar, London. Since they are used for air input only, the grilles are mounted with their blades running across the lines of lighting units.

system for a false ceiling in which lighting, air conditioning and other facilities can be provided. It is designed to accept almost all standard types of ceiling tile without modification, although there are one or two proprietary makes which require special adaptation. To develop the system a team of fitting designers, lighting engineers, ceiling contractors and heating and ventilating engineers had to be set up. Thorn Lighting is perhaps unique in being able to provide such a team from its own resources, but even though all its members were working for the same company it is surprising how complicated it was to integrate their efforts: the design and production of the system taught a great many lessons in the art of communications and co-operation.

The basic unit of the Arena system is a sheet steel box, 1 800 mm long by 300 mm wide, made in three flange styles, each providing for the three principal kinds of suspended ceiling. These boxes, which will accommodate the fluorescent lamps and their control and optical systems, are hung on modular stations from a grid previously installed by the ceiling contractor. Other, smaller boxes, which may contain air diffusing or extract equipment or public address equipment or may simply be infill panels, are fixed in line with them, so that the whole assembly provides the main structural support for the ceiling tiles. Both the main ceiling boxes and the ancillary boxes between them are provided with wiring channels so that the whole assembly forms a trunking system into which can be drawn the cables feeding the electrical equipment. In addition, Atlas Liteline trunking and specially adapted linear air diffusers are included in the overall concept and these are also hung from the basic grid.

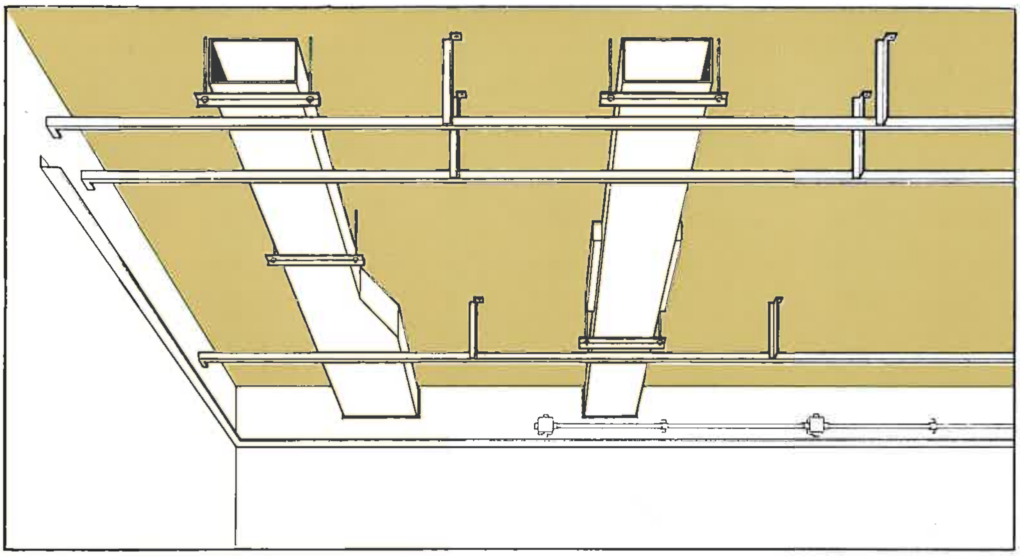
Thus in one design the main problem of fixing the lighting fittings and

Installing ceiling tiles in a lay-in system. The input grille is omitted to show the input cone and flexible air duct above.

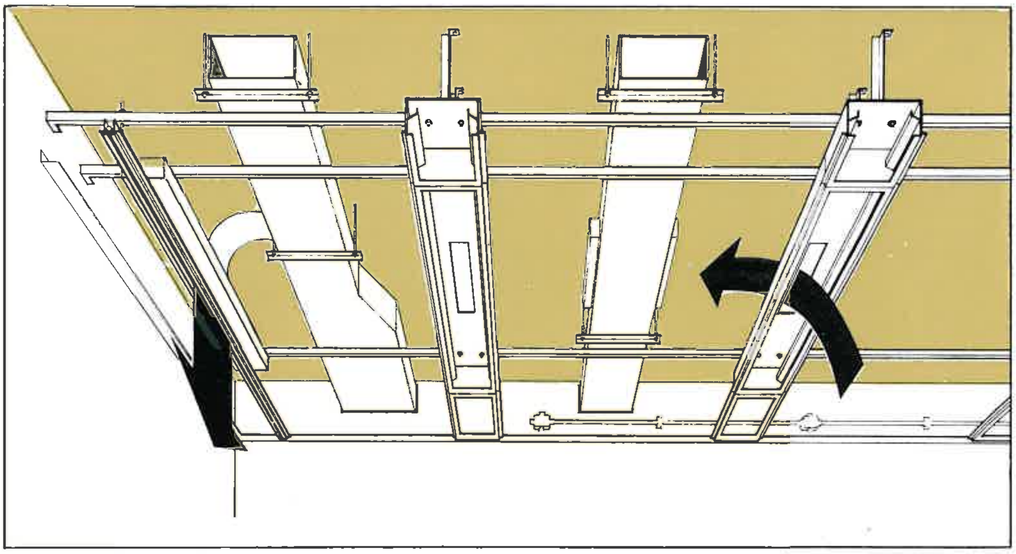
co-ordinating them with the suspended ceiling is solved. The positioning of the basic grid and of the ceiling box and other units which hang from it must be the responsibility of the ceiling contractor. The electrical contractor instals his main supply cables, terminating at connecting boxes in suitable positions for eventual coupling to the ceiling boxes, long before the ceiling contractor arrives. He then has nothing more to do until the ceiling contractor has installed the basic suspension components when he draws his cables into the channels provided and connects them to the mains. The gear trays, lamps and optical equipment are installed after the ceiling contractor has finished. No adjustments or levelling are necessary because all this was done by the ceiling contractor when he installed the basic grid on which all other components depend. In the same way, if air conditioning is needed, the main runs of ducting are fixed to the structural slab before the ceiling contractor starts his work, after which the sole responsibility of the ductwork fitter is to connect them to the terminal hardware which forms part of the Arena system. No work has to be done after the ceiling contractor has installed his tiles, so that the risk of damage to the finished ceiling is minimised.
The Arena system marks a real advance in technique, but experience in developing it has demonstrated how essential it is that everyone concerned with its installation should know exactly what he has to do and where his responsibility begins and ends. Not the least important part of the operation has been the preparation of a handbook giving full details of all components, including photometric and air-handling data, and a clear explanation of installation procedure. The necessity of clarifying these details contributed not a little to the practicality of the design. The Arena system will make integrated environmental designs not easy but at any rate a great deal less difficult to engineer and install.

The two-way air input grille is installed. This must be done before all the tiles are in position.

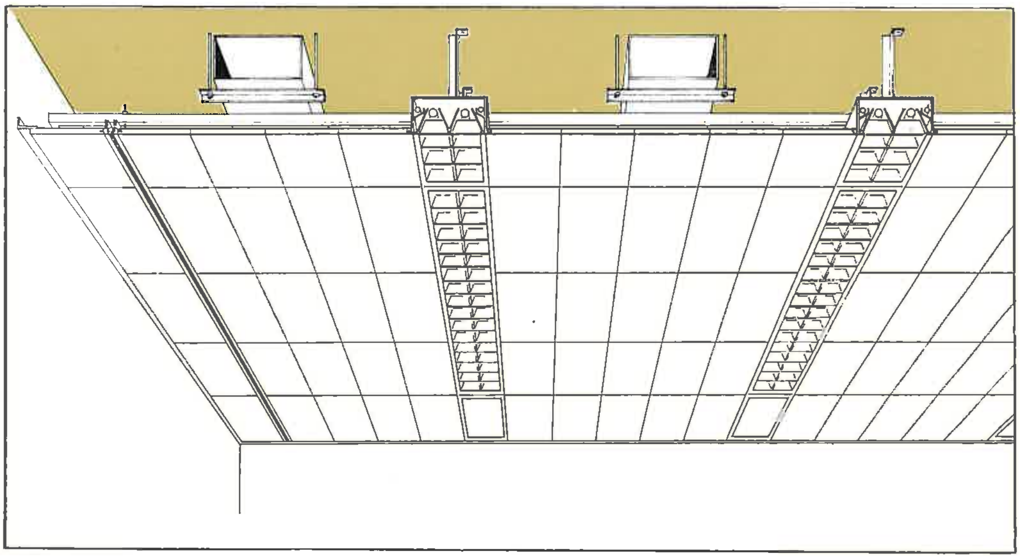
After the main wiring and feeds to other services (including air-handling ducting if required) have been fixed to the structural slab, **the Ceiling Contractor** fixes and levels the sub-support frame, a system of cross channels to support the ARENA components, and installs the trims at the edges of the ceiling. This frame usually consists of standard channel sections suspended as close to the structural ceiling as possible. In some cases independent fixing brackets may be necessary.

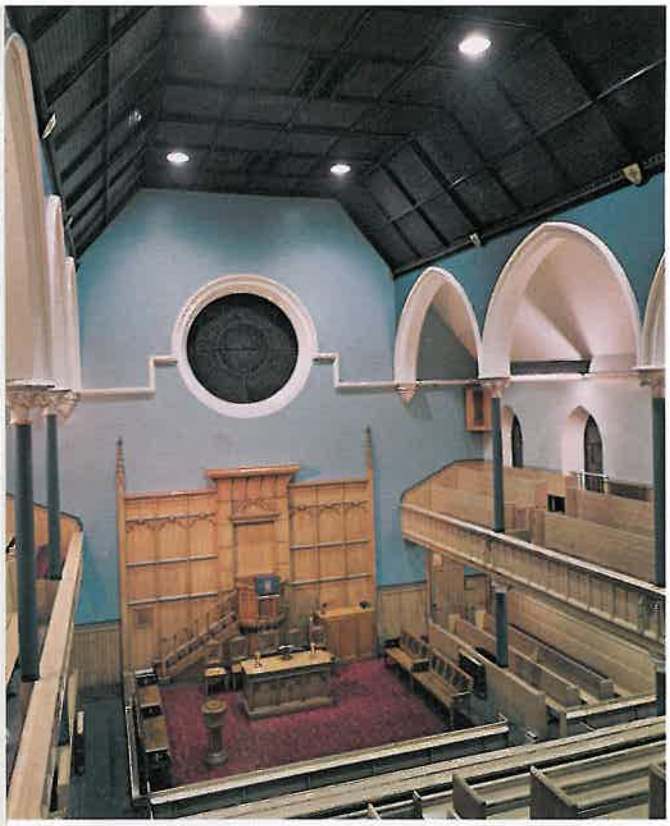


He then installs the ARENA ceiling boxes, electrical trunking and linear air diffusers with their accessories as required. The **Electrical Contractor** makes his connections, including through wiring in the ceiling boxes and gear trays, fluorescent lamp and light control equipment are installed in the ceiling boxes. Where necessary, the **Air Conditioning Engineer** connects the main ducting to the terminal air devices.



Finally **the Ceiling Contractor** installs the ceiling tiles to complete the ceiling.





Thorn Kolorlux and Kolorarc discharge lamps are being increasingly adopted for interior lighting. The cover picture shows Kolorlux in a chemical laboratory at the Woolfson Institute in Strathclyde University, while the illustration at *left* shows the same lamps used to light a church in Glasgow. *Below:* British European Airways' repair hangar at Heathrow-London Aiprort, is lit to high intensity by groups of four high-bay fittings using both Kolorlux and Kolorarc lamps.
On the *facing page* is the National Westminster Bank in Colmore Row, Birmingham, where Kolorlux lamps are used in special air-handling fittings in a coffered ceiling finished in gold leaf.


Enquiries

colour and visual clarity

by H E Bellchambers CEng MIEE FIllumES *and* A C Godby

Introduction

For precise measurement, examination and matching of coloured surfaces and materials, artificial light sources having a spectral power distribution close to that of some agreed phase of daylight are a fundamental necessity. For the lighting of most interiors, however, the spectral quality is of less importance, because in a complex visual scene the eye adapts to these conditions and in part compensates for minor deficiences. There has been a continued drive towards the development for general lighting purposes of artificial sources which have a spectral quality approaching that of some phase of daylight; and this development has been influenced by the related need to provide adequate quantities of light at economic cost. It is generally accepted that psychologically an artificial light source which provides a warm appearance is preferred at low values of illuminance, but that at higher values a cooler appearance is preferred.

To satisfy the demand for high levels of general lighting, light-source development has tended to put greater stress on luminous efficacy and warm colour appearance than on spectral quality; and because there are undoubted benefits to be gained from relatively high values of illuminance it has been generally held that increases in illuminance can largely compensate for some defects in spectral quality.

For these reasons a range of tubular fluorescent lamps has been evolved for general lighting applications so that a choice can be made regarding spectral quality and illumination quantity, depending on the purposes for which the lighting is required. However, with the increasing use of higher levels of illuminance in modern interiors the need for warm appearance lighting is diminishing.

Visual clarity

For a given value of illuminance (assuming this is adequate for the purpose) it is generally accepted that a well-designed and balanced interior colour scheme will be more attractive when illuminated by fluorescent lamps giving good colour rendering than when illuminated by a source with a poorer spectral quality. Observation has shown that the attractiveness is not due to the quality of the colour rendering of individual hues alone, but that some additional factor, which has been referred to as 'visual clarity', adds to the attractiveness of the interior.

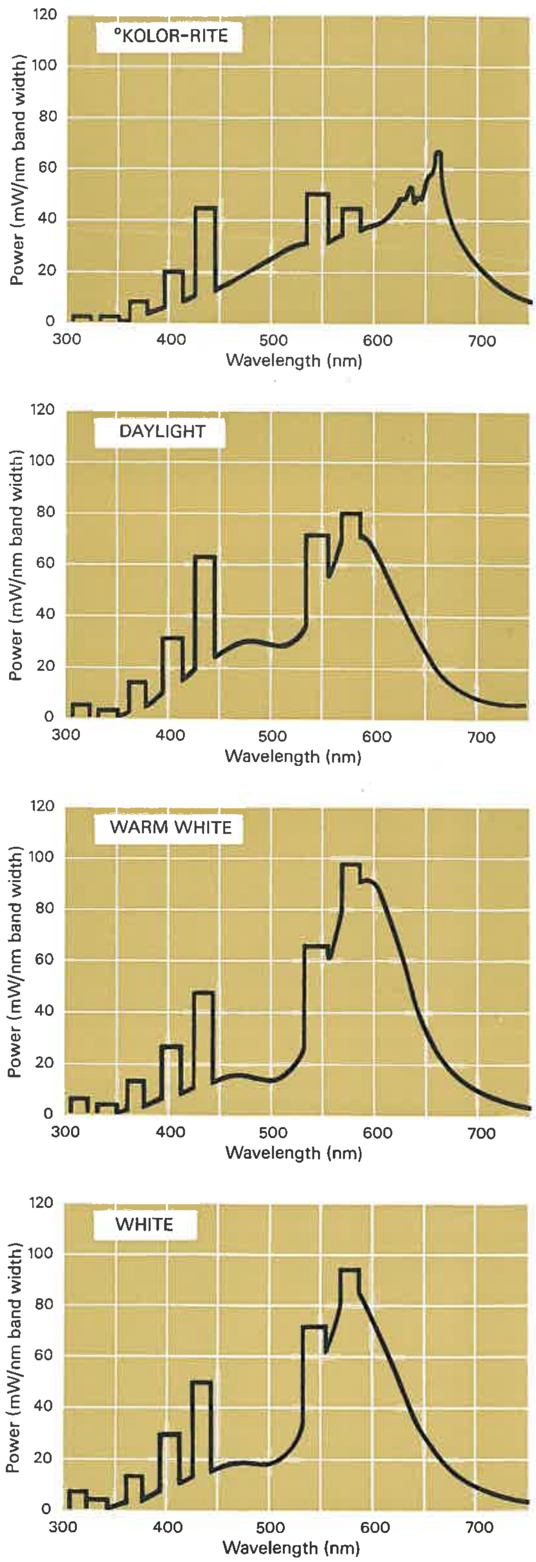
Other observers have commented that when some interiors are illuminated by high efficacy lamps a veiling effect is seen on coloured objects and surfaces, especially at the borderlines between one surface and another, which is not apparent in natural daylight. These effects are generally not so great as to cause any serious errors of perception or so large as to reduce significantly visual acuity or task performance. The attractiveness of an interior will be determined by the pattern of colour, the juxtaposition, area, lightness and brightness of each part, and by surface texture. Hue, value and chroma must be balanced against shape, form and proportions, but this balance is easily destroyed if a carefully chosen colour pattern is distorted by lighting which has an unbalanced spectral power distribution. The size and proportions of differently coloured areas can be apparently changed by changing the colour of the lighting.

A comparison of the spectral power distribution of high luminous efficacy sources shows that the high luminous efficacy is obtained by increasing the relative spectral emission in those regions of the spectrum where the eye response is greatest and, conversely, that sources with a balanced spectral distribution have a lower luminous efficacy.

In those wavebands where the eye response is less than the peak value, for sources with a balanced spectral power distribution, the emission can be equal to or greater than that of the high efficacy sources. Thus the luminance of many coloured materials illuminated by a source with a balanced spectral power distribution can be equal to or higher than that obtained using a high efficacy source of the same total power and, consequently, the apparent brightness of surfaces reflecting light in those wavebands which are outside the region of high emission will be lower when illuminated by high efficacy sources than when seen under a good colour rendering source. Furthermore, the spectral reflectance of many materials and surfaces, although predominantly of a single hue, responds to radiation in other regions of the spectrum and hence colours may in some instances be degraded by accentuating the fringe responses and in other instances by exaggerating the predominant hue. Other experimenters have shown that white surfaces illuminated by cool, high colour temperature sources appear brighter than when illuminated by warm low colour temperature sources of the same luminance.

Therefore it is to be expected that there will be a degradation in the quality and character of the interior in installations using light sources which have deficiencies in certain wavebands compared with those lit by sources with spectral power distributions following closely those of some phase of daylight.

Figure 1 Spectral power distribution curves for 5ft lamps at 65W.



Tests

In a preliminary experiment to obtain a measure of the loss of visual clarity when using high efficacy lamps, two identical cabinets with mechanically controlled variable output fluorescent lamps, containing objects common to both, were used. One cabinet was illuminated by tubular fluorescent lamps with good colour rendering properties and the other by lamps of high luminous efficacy. The observers stood in front of the two cabinets so as to have a full view of both; and were able to control the illuminance in one of them by means of a dimmer. Tests were made by comparing °Kolor-rite lamps with Daylight, Warm White and White lamps. Spectral power distribution curves for these lamps are given in Figure 1.

The cabinet containing the high efficacy source was in turn set at 200, 400 and 800 lux and observers were requested to adjust the value of illuminance in the other cabinet until they were satisfied that the overall clarity of the scene was the same in both cabinets.

Results

Results are given in Figures 2, 3 and 4 (overleaf) and show that the °Kolor-rite lamps not only provide better colour qualities but give a higher degree of visual clarity than do high efficacy lamps at the same value of illuminance. Comments made by observers were also recorded. The main point mentioned was that the obvious differences in colour rendering of the two lamps in each test made subjective judgments of visual clarity difficult, but that the cabinet containing the °Kolor-rite lamps always had a cleaner, more vital appearance than the other cabinet.

Tests in experimental rooms

The results of these tests were queried because they could strictly apply only to the conditions of the tests and might be different in real situations in rooms; so the study was extended. Two small rooms, each 8ft (2.4m) wide, 8ft deep and 8ft high, were erected side by side. These rooms were furnished in an identical manner and were illuminated by identical luminaires, each having mechanically controlled light output designed to maintain the same light distribution at all levels of illuminance.

In these rooms the ceilings are white and the undraped parts of the walls are neutral grey. A small white area forming the background to the framed wall paintings (by A C Godby) was positioned to serve as a reference area for the source colour appearance and to receive a relatively high level of direct illuminance. No light was allowed to enter the rooms from outside, and the observer sat in a chair placed so that he could see both rooms. Sixty observers took part in these tests.

The comparisons made in these rooms were between the same lamps as in the first experiment but included an experimental lamp having the colour appearance of the °Kolor-rite lamp but with different colour rendering properties.

The illuminance was set in turn at 200, 400 and 600 lux and the instructions to the observers were similar to those given in the earlier tests.

Results in rooms

The results of the earlier tests using the two cabinets were largely confirmed; there were, however, some differences. For each of the high efficacy lamps the difference in illuminance between these lamps and the °Kolor-rite lamp for equal clarity remained nearly constant over the illuminance range of 200 to 600 lux, instead of increasing with the illumination as it had done previously. This may have been due to a larger number of observers having been employed, giving a wider spread in the results. The range of illuminance in the cabinets was 200-800 lux and this too may have affected the results. The average difference taken over this range and for each of the high efficacy lamps was approximately 25% of that of the °Kolor-rite lamp.

The results of the tests in which the experimental lamp, having a colour appearance similar to that of the °Kolor-rite lamp but of higher efficacy and different colour rendering, was included to indicate that colour appearance as well as colour rendering plays a part in the assessment of visual clarity.

In a separate series of tests using the experimental rooms, in which eight expert observers took part, comparisons were made between Warm White and °Kolor-rite lamps and settings were made for equal illuminance, equal clarity and equal pleasantness. The results of these tests show that there is little difference between equality of clarity and equality of pleasantness. These observers agreed that visual clarity was an apt description of the phenomena they experienced.

Conclusion

The results of these experiments show clearly that when compared subjectively °Kolor-rite and other lamps having spectral power distribution close to some given phase of daylight not only provide better colour rendering but give a higher degree of visual clarity than do higher efficacy lamps at equal values of illuminance.

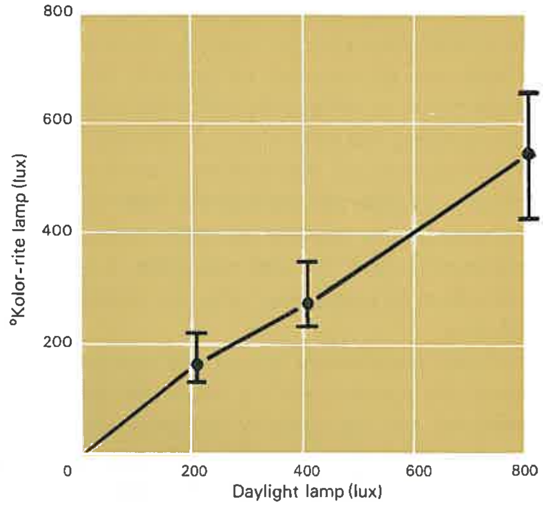


Figure 2 Relationship between Daylight and °Kolor-rite lamps for equal satisfaction.

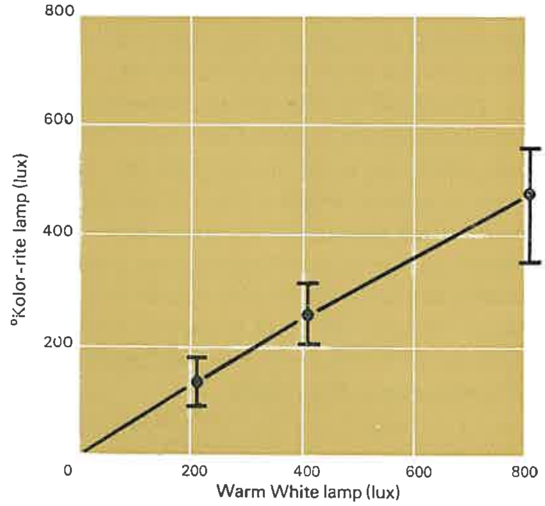


Figure 3 Relationship between Warm White and °Kolor-rite lamps for equal satisfaction.

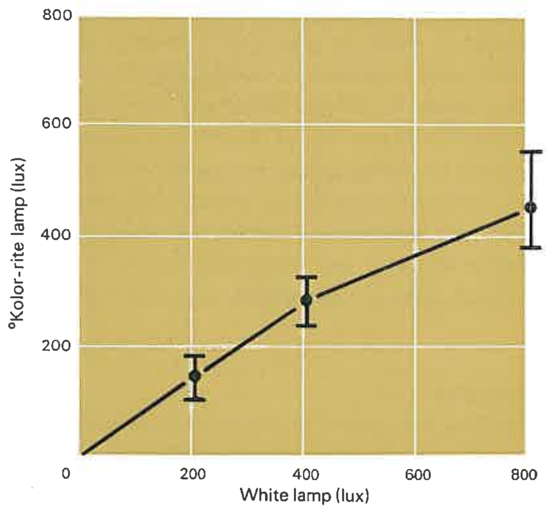
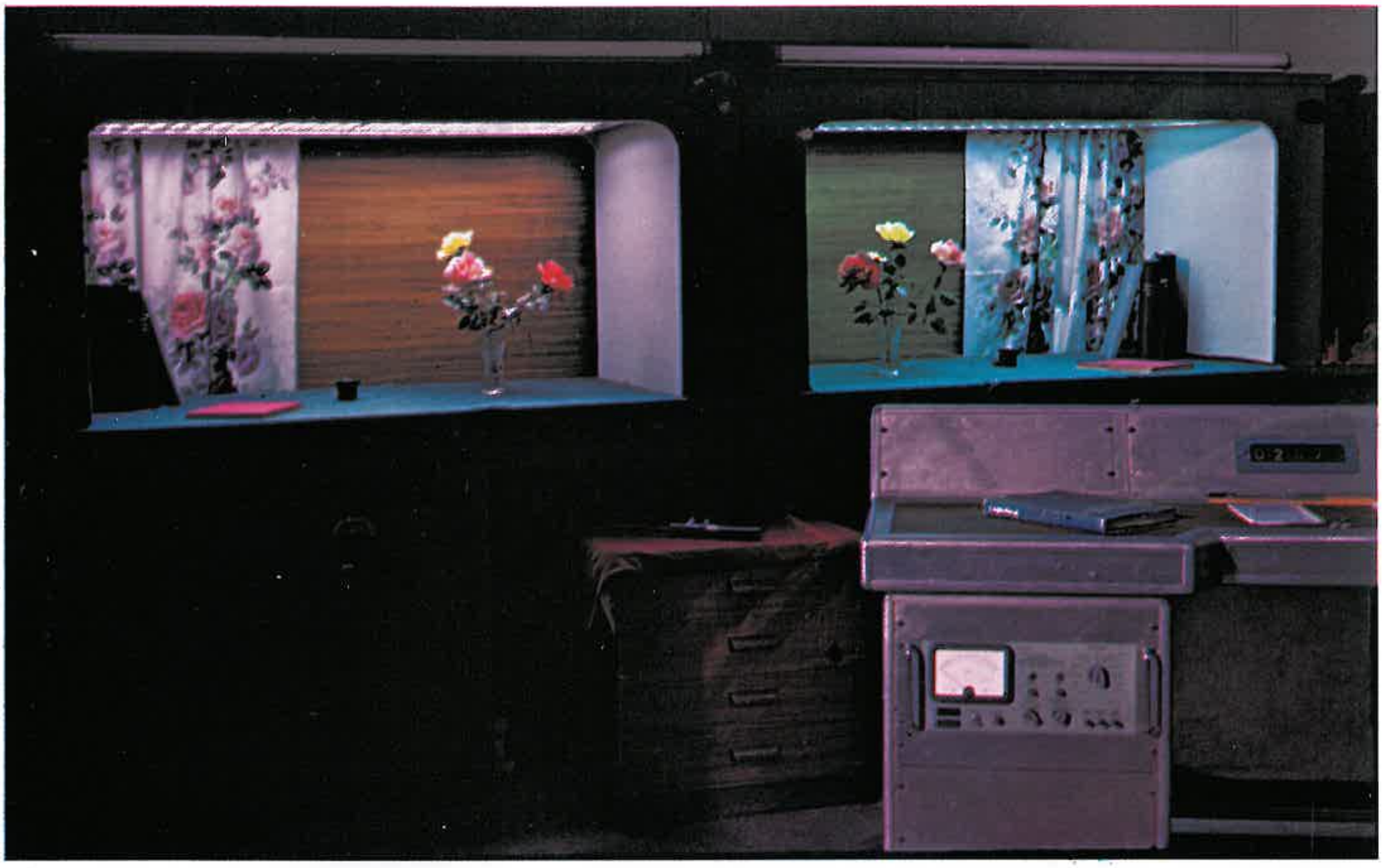


Figure 4 Relationship between White and °Kolor-rite lamps for equal satisfaction.



Above: the two identical viewing cabinets used in the first series of experiments. The control console used by the observers is on the right.

Top right: One of the two identical room settings. This is the view which would present itself to the observer. *Below:* the two rooms together; the degradation of colour under the higher efficacy source is clearly apparent.

international co-operation in lighting

by W K Lumsden M Illum ES

Organisations like the Illuminating Engineering Society exist in all technically developed countries. The American society, founded in 1909, is the oldest and has the same name as the British one which came into being a year or two later. In France there is the Société des Eclairagistes Français, in Germany Das deutsche Lichtechnische Gesellschaft. All these societies support the International Commission on Illumination (CIE), an organisation concerned with increasing our knowledge of lighting through the work of expert committees, providing a platform for the exchange of ideas on lighting between lighting people from different countries and helping to promote international standards for performance of lighting. The presidency is passed on from country to country every four years and for the present session (1971-1975) the president is Mr W R Stevens of Britain.

Once every four years the CIE organises a conference which is attended by international experts delegated by their national societies. The last such conference was held in Barcelona last September. During the intervening periods work is carried out on many different aspects of lighting by other committees of experts or working parties. Usually efforts are directed towards producing useful work and reports during each four-year term.

Britain is represented on many committees and Thorn Lighting takes a considerable part in the work of the CIE, as indeed it does in the IES. Thorn people involved include Miss Margaret Halstead on colour rendering, Dr A M Marsden on visual performance, Mr Harold Bellchambers on lighting calculations, Mr Harry Hewitt and the author on the committee concerned with lighting of the environment, and Mr A Wilcock who has been secretary of the British delegation.

The pattern of activity for each of the expert committees follows similar lines and it may be of interest to follow the processes involved in a typical four-year term.

Mr Hewitt is chairman of the expert committee E.3.1.1.3. concerned with lighting and the environment; the writer is secretary and the committee is composed of members of our own IES and of similar societies in other countries. Initially the committee discussed its past work and decided on objectives to be achieved during the following three and a half years. In particular, the meeting agreed to produce a tentative proposal for designing good quality installations. During the following year work was done on this proposition with the willing assistance of the lighting engineers in Thorn Lighting regional offices in making appraisals at night, taking measurements of many interiors and photographing some of them. Help was also given by the Lighting Development Groups at both Enfield and Leicester, and, of course, by other members of the IES, so that by the time the next meeting was due a considerable body of material had been collected. A meeting was held in Paris in the spring of 1969 at which the draft results of this work were presented.

The committee met again in the spring of 1970 at an IES conference

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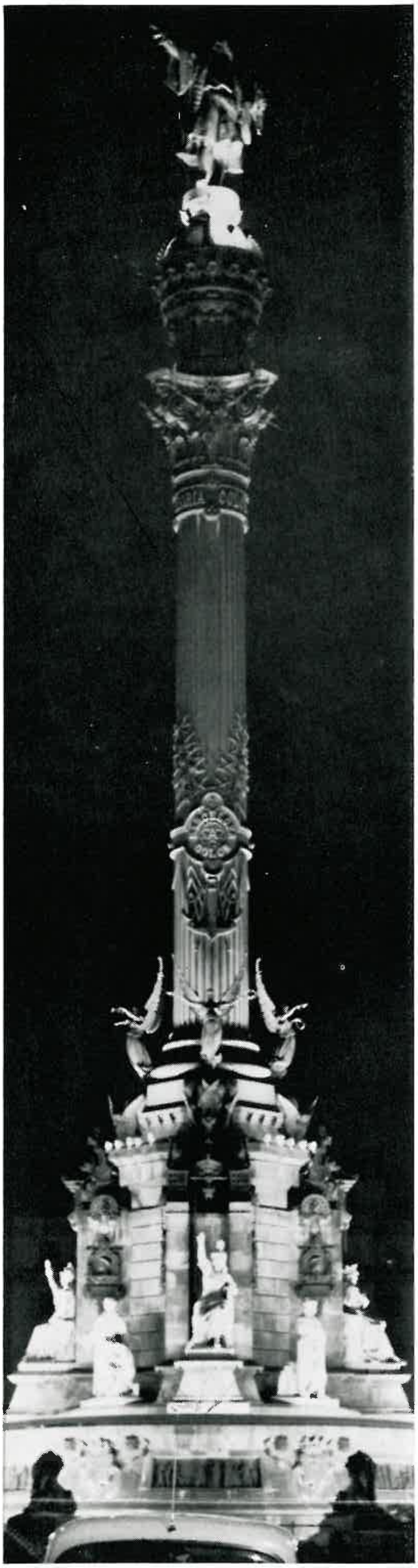

Left: The floodlit Columbus memorial in Barcelona. *Above:* the Pueblo Español. *Below:* floodlit fountains in the Plaza Cataluna.
Photographs by G F Cole, Secretary of the IES.

at York where further developments were reported, one of which was the proposal of a technique for the appraisal of installations from coloured slides. This method has obvious advantages over the lengthy and laborious technique described by Dr Marsden in *Lighting Journal* no. 6. The committee was convened for the last time in Moscow in January 1971. At this final meeting before Barcelona, the results of the work to date were presented; the Russians became involved in appraising colour slides and it is interesting to note that their judgment of the slides tied in with that of a group of architects and engineers in Manchester.

The international experts considered that the work done was important enough to warrant being presented to the CIE conference in the form of a written paper and this was offered to the organizing committee. The committee approved the content of the paper but could not find time to present it in the conference meetings. However at the technical session held on this subject at Barcelona the chairman referred to the difficulty of defining this area of work. He said that he and his colleagues were continuing to remind themselves and others that there is more to lighting than illuminance and glare factors. They realised that they were working in a difficult area and he hoped that they had defined their activities by the statement that they were concerned more with the environment than the task, with preference more than performance and with quality rather than quantity. He referred to the work outlined above and during the discussion accounts of appraisal work were given by delegates from France, Australia and Britain. Interest in this subject is growing and this was confirmed by the presence of over 50 delegates at the sessions, including an impressive number from the USA.

Having looked at the work of one committee, it may be of interest to examine the way in which the conference is run. Last year saw a record attendance of over 700 delegates, from Argentina, Australia, Austria, Belgium, Canada, Czechoslovakia, Denmark, Eire, Finland, France, Germany, Hungary, Iran, Iceland, Israel, Italy, Japan, Mexico, the Netherlands, Norway, Poland, Portugal, Rumania, South Africa, Spain, Sweden, Switzerland, Turkey, the UK, USA, USSR, Venezuela and Yugoslavia. The president was Mr D Vermeulen of the Netherlands and the British delegation was led by Mr J G Holmes.

There were general sessions during the first three days at which the technical committees reported progress. On the fourth day there were two parallel meetings at which papers were presented. For three days the technical committees went into detailed discussions and as many as six meetings took place at the same time.

Papers on colour rendering were read by a Japanese team and another British one including Miss Halstead; Mr Bellchambers presented a paper on visual clarity, the substance of which appears in another part of this journal. The programme included sessions on almost all important lighting topics, including photometry, colorimetry, visual performance, discomfort, lighting calculations, light-sources and materials. Daylighting was also the subject of a committee (set up in 1927) and there were sessions on streetlighting, exterior lighting, automobile and theatre lighting, education, codes and legislation and theatre lighting. The last-named provoked the characteristic comment from Mr F Bentham that it 'finished with a flurry of slides the wrong way round, sideways and finally upside down—the last appropriately being from Australia.'

Enough has been written to show that attendance at the conference was not entirely a holiday but there were of course lighter moments. Barcelona was en fête and floodlit and the social functions included a dinner in the floodlit gardens of the Albeniz Palace and an al fresco dinner and entertainment in the Pueblo Español.

automobile auxiliary lamps

by F Woodward CEng MIMechE

As readers of the article New Lamps for Vehicle Lighting in the last issue of *Lighting Journal* are aware, much has been said and written about developments in auto headlights, foglights and spotlights where the introduction of tungsten-halogen sources has resulted in dramatic improvements in performance. Such improvements are immediately seen and recognised by drivers and pedestrians alike. During this period developments have also been proceeding in the auxiliary lighting of vehicles and, while not all of these are so apparent to the driver, they nevertheless play their part in improving costs and/or performance.

Wedge-based lamps used in a printed circuit as part of a control panel.

Panel lighting

As part of the much publicised safety campaign in the United States, all vehicles there will shortly be required to be provided with illumination on the essential controls, e.g. ignition switch, windscreen washer, windscreen wiper, de-mister, etc., and it may be speculated that such improvements will ultimately be extended to vehicles for the British market. Individual control illumination will obviously require new techniques and systems utilizing the 5mm wedge base lamps would seem to provide at least one answer.

The past few years have seen an almost complete changeover in panel lighting whereby the earlier technique of illuminating instruments and warning lights by means of capped lamps in sockets has been superseded by a system using printed circuitry complete with wedge base lamps.

This technique involves the use of a snap-in socket which is mechanically located in the printed circuit and into which the lamp is inserted. In effect, only three components are needed: the plastic panel carrying the printed circuit, the spring-in sockets and the wedge base lamps. The method employed is as follows. A typical panel is moulded in plastic with bevelled openings at the lamp position such that shaped contact plates on the side of the socket may be sprung in, trapping exposed sections of a flexible printed circuit both to retain the socket and establish electrical contact. The use of wedge base lamps in this manner results in a substantial saving in assembly time as the process involves only pushing the lamps into sockets and the sockets into the panel apertures. All soldering, crimping and push-on electrical connections are eliminated.

Wedge base lamps

The wedge base lamp is made without the usual metal screw or bayonet cap but, instead, has a closely controlled profile moulded on to the base of the bulb. This form includes grooves which are retained by springs in the socket which also make electrical contact by

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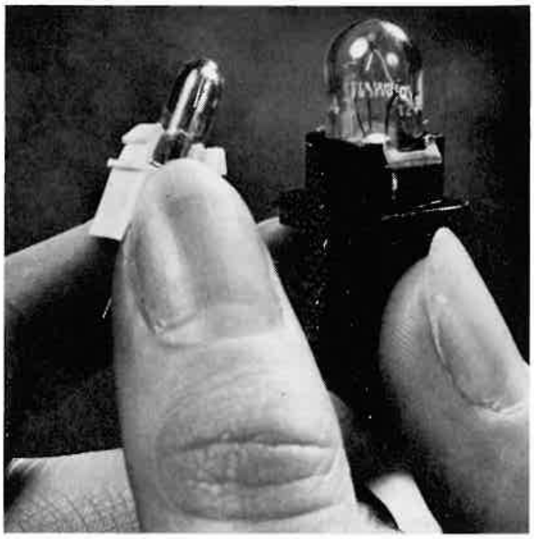
pressing against extended lamp lead wires doubled back against the glass base.
The 10 mm diameter version of the wedge base lamp has been used for some years in a range of wattages designed to give the panel designer some freedom of choice in respect of wattage and light output. Applications vary to the point that where some lamps are required to provide a relatively high lumen output in order to light an instrument satisfactorily, others demand much lower levels in order to avoid causing problems of glare.



The 1·2W 5 mm diameter wedge-base lamp compared with the older 10 mm version.

Heat from lamps

A common difficulty in instrument illumination is that of coping with the heat from lamps, particularly as assemblies are often constructed from thermoplastic materials of fairly low softening temperatures, and this has proved to be the deciding factor for lamp wattage in many cases.
Because of this a range of vacuum lamps between 1.5 and 3 watts is manufactured. These 10 mm diameter panel indicator lamps, which are usually designed for lives in excess of 1 000 hours at the rated voltage, give sufficient light without causing heating problems. A 5 watt gasfilled lamp is also made in this outline but as it is designed primarily for external lighting of vehicles it has a higher luminous efficacy with a consequent shorter life. This lamp is nevertheless occasionally used in panels where a high light output is essential. A 1.2 watt 5 mm diameter version of the wedge base lamp is now finding increasing use for panel lighting and the compact dimensions of this remarkably small lamp make it particularly attractive where space is limited.

Side and tail lamps

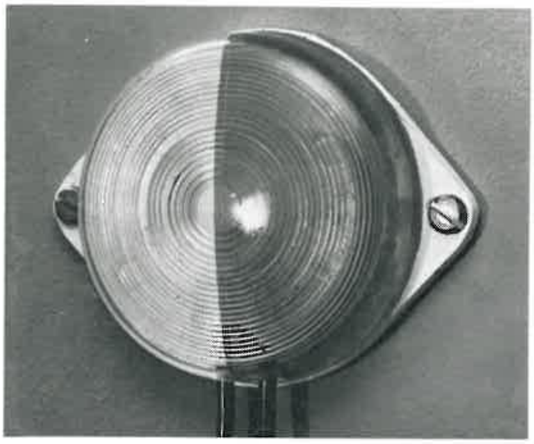
The use of wedge base lamps is by no means confined to the instrument panel. Side and tail lamp types are also available and the 5 watt lamp referred to above is included in the draft European Regulation for Standard Auto Auxiliary Lamps which lists the specific lamp types to be used in the external lighting fittings on vehicles, e.g. lights for side and tail, rear registration plates, stop tail lights and direction indicators. The 5 watt wedge base lamp is used on many vehicles fitted with sealed beam headlights without having a separate sidelight fitting; the wedge base lamp is mounted behind a clear window in the aluminised reflector of the sealed beam lamp so as to provide an effective side light.

Thorn Markerlights

The hazards presented by long vehicles crossing road intersections and making right-angle turns have long been recognised by motorists and legislation has now been introduced which requires vehicles over 60 ft (18 m) and trailers over 30 ft (9 m) in length to carry side-marker lights. These devices are required to be placed on the sides of such vehicles in order that their presence can more readily be detected when they are across the normal traffic flow. The side-marker light is a two-part fitting with separate white and red sections which identify the forward and rear ends of the vehicle.
The legal requirements are for basic minimum markers to be fitted but it will be appreciated that considerable improvements in recognition will result from the use of additional units.
The Thorn Markerlight not only fulfils the requirements of the law but is the first British integral unit in which a long-life lamp is permanently sealed into a plastic housing. The front cover incorporates the fresnel lens across both the white and red sections which

provides, from a 3 watt lamp only, a signal more powerful than many marker lights using 5 watt lamps. The sealed unit is designed to maintain a high performance throughout life and is made to a very shallow depth so as to reduce its protrusion from the side of the vehicle and thus the likelihood of breakage.
A further version of the Thorn Markerlight is made with a completely red lens suitable for fitting to the rear ends of large vehicles or trailers in addition to the statutory tail lamp. In view of the recent multiple crashes on the M1 and other motorways, the use of such markers might well be extended to vehicles other than large trucks and trailers and should be particularly attractive to owners of caravans, smaller trucks and pick-ups.

Conclusion
There is little doubt that the influence of the European auto lighting regulations, which are just beginning to take effect, and the United States regulations will have a major impact on the standard of vehicle lighting. Most effort to date has been concentrated on external fittings and perhaps one of the most noticeable features will be the introduction of the two-level (night/day) system on turn indicators and brake lights on UK vehicles in 1973. This system results in more intense signals for daylight operation so that the vehicle can be more easily seen in bright and sunny conditions, but for the night time glare effect to be reduced by a considerable lowering of intensity when the car's lights are switched on.
However, more attention is now being paid to internal lighting and the necessity for effective instrument and control illumination together with instantly registered warning lights is occupying the attention of designers.
Lighting developments are keeping pace with these new demands, all of which will play a part in improving safety on the road and comfort in driving.



Thorn Markerlight. The night-time picture below shows the value of this extra light.

selective reflection coatings

by W J McLintic MBKS

In an ordinary mirror, made of solid metal, or of glass with a silver or aluminium coating on one surface, the whole range of visible light is more or less equally well reflected, and so also are the infra-red and ultra-violet rays, which are both invisible.

Some metals, like gold, reflect certain colours better while some are much better reflectors than others. It could be said that polished gold, among the good reflectors, is selective in that it is especially effective in reflecting yellowish light.

In the 1930s studies of the phenomenon of interference led to the development of a new form of reflector which has become increasingly available for commercial purposes. These mirrors are selective: their reflectance can be very high for some part of the radiation and very low for the remainder. Thus we have a 'cold' mirror which reflects visible and transmits infra-red, a 'hot' mirror which does the reverse, and colour reflecting filters which can separate the various colour bands in the visible range. Such filters are known as dichroic or interference filters.

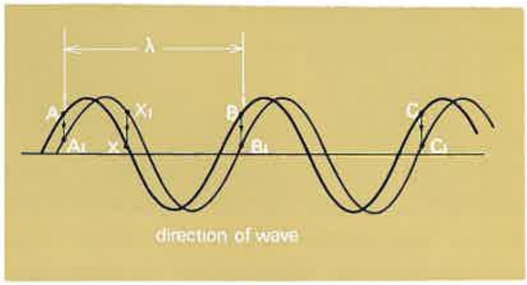


Figure 1 A, B and C are corresponding points (i.e. in phase). As the wave moves to the right A, B and C move downwards to position A_1, B_1 and C_1. Point X is not in phase with A, B and C, and moves up.

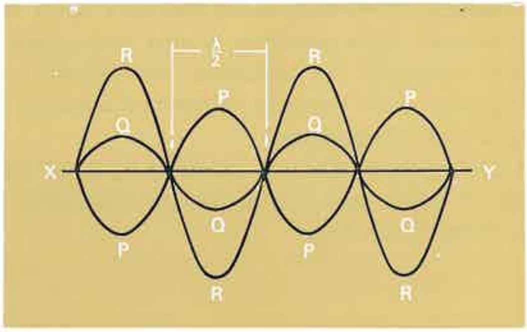


Figure 2 Wavelength P is a half wavelength behind R. If the distance from R to XY is greater than that of P to XY, a resultant wave Q is produced.

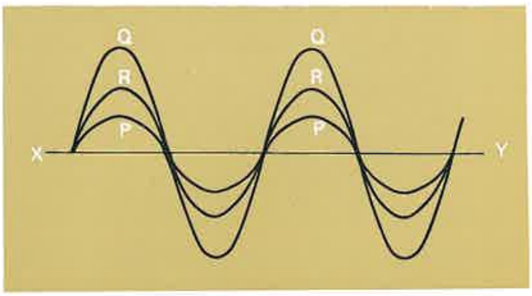


Figure 3 Two waves R and P are in phase but of different displacement. They reinforce each other to produce the resultant Q.

Wave theory of light

Light is part of a range of electro-magnetic radiation extending from long-wave radio at one end of the scale to ultra-short wave cosmic rays at the other. This radiation is characterised by one basic feature—its velocity of propagation in vacuo. The various parts, infra-red, cosmic, etc., are distinguished by their wavelength or their frequency.

A much simplified analogy is seen when we drop a stone into a still stretch of water. Because of the elastic nature of the water surface a system of concentric waves travels outwards from the centre, the distance between adjacent waves and the speed of consecutive waves being constant. It is only the wave that moves outwards; any particle floating on the surface merely moves up and down.

These observations can be represented by a drawing (Figure 1) of a vertical section of the waves, from which we can establish the wavelength. The frequency is simply the number of wavelengths which pass a given point in unit time (one second); multiplying these two gives the velocity.

The outline is continuous from wave to wave and the shape is the same above the mean level (still water surface) as below it, as can be seen by inverting the drawing. Points in corresponding positions on the outline of the waves are said to be in the same phase. This word indicates the state at a particular instant of some object, e.g. a particle on the surface, undergoing a regularly recurring change in displacement from the mean level. Obviously, for any one reference point there is only one corresponding position on each wave; all other positions are out of phase with the reference point, the extreme case being at a position half a wavelength or any odd number of half wavelengths away from this point.

Similarly, we could have two sources of radiation starting at the same time (Figures 2 and 3) and if the wavelength is the same for both we may find points on one wave motion which correspond, or are in phase with points on the other—provided that "at the same time"

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means that at any instant the corresponding points are moving at the same speed and in the same sense (up or down in the diagram). This is saying, in fact, that all points on one wave motion have corresponding points on the other and both series of waves are completely in phase. For our purposes we are concerned only with wave motions which are either exactly in phase, or directly out of phase.These are shown in the figures, and it can be seen that in a situation where the motions are in the same medium and in the same direction they tend to reinforce each other when in phase and to cancel each other when out of phase by a half wavelength. It is important to grasp this idea, as it is basic to the argument that follows.

These effects are known as constructive and destructive interference and, although there are many mechanical examples of this in nature, one has to stretch the imagination somewhat to apply the idea to the very small wavelengths in visible range. Some idea of this may be grasped when it is realised that the velocity of electromagnetic vibration is about 300 million metres per second. Thus, for yellow-green light wavelength (λ) is .00000055 metres, frequency = 545 million million waves per second. We are mainly interested in the in-phase and out-of-phase situations; these are equivalent to the propagations being in step, or out of step by a half wavelength, although we must also take account of their relative values of intensity.

Refractive index

Transparent materials can all be classified as to optical 'density'. This is a measure of the velocity at which light will pass through them, and the value is called refractive index. Reflection occurs at boundary surfaces between transparent materials of different refractive index, and when light is travelling from a low to a high material (air to glass) a phase change of a half wavelength takes place in the reflected beam. On the other hand when crossing a boundary from a high to a low refractive index no phase change occurs (Figure 4). In addition, by reducing the thickness of a material to a value of one quarter wavelength, an out-of-step difference of a half wavelength (Figure 5) will exist between reflected light from the first surface and that reflected back from the second surface, because of the time lost in passing twice through the material. Note that in the diagrams light is shown striking the surface at an angle. This is done for clarity, but in fact all these considerations strictly apply to incident light which is normal to the surfaces.

How can we use these facts to our advantage? The answer is shown in Figures 5 and 6 where the effect of adding a low index layer and a high index layer to a glass substrate is explained (low and high meaning relative to the refractive index of glass). Assuming the layer thickness to be one quarter wavelength the reflectance for one layer on glass can be calculated from

$$R = \frac{(nf^2 - na.ng)^2}{(nf^2 - na.ng)^2 \quad ng}$$

where nf = refractive index of film
na = refractive index of air
ng = refractive index of glass.

In other words, the effect of adding a layer of low refractive index is to reduce the reflection at a given frequency, as shown in Figure 5, while adding one of high refractive index is to increase it, as in Figure 6 (see also Figures 2 and 3).

The greater the difference between the 'n' of one film and that of the glass, the greater the change in reflectance. Since the glass base on which the film is built has a refractive index of about 1.5, and the lower limit is 1.0, that of air, there is a range of between 1.0 and 1.5 for the material with the lower index, and there are several with a refractive index above 2.0. Commonly used materials are magnesium

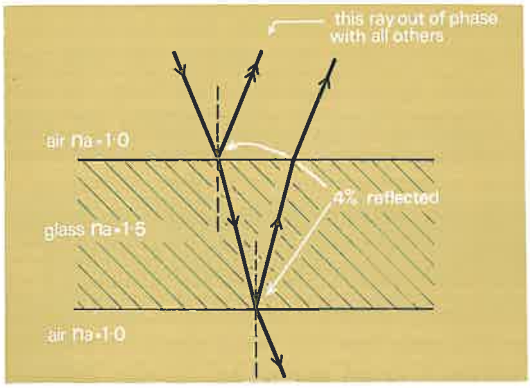


Figure 4 Reflection from a glass plate. The reflection is out of phase with other rays because of a change from low to high refractive index.

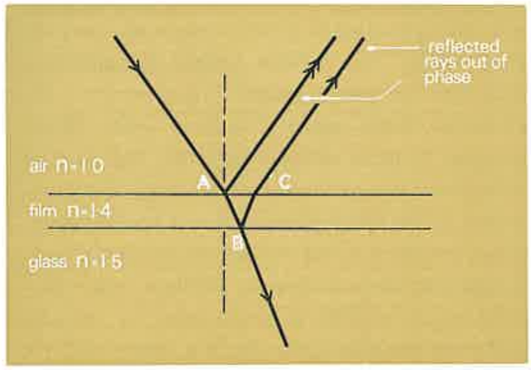


Figure 5 Anti-reflection layer on the upper surface of the glass. A film of thickness $\frac{1}{4}\lambda$ and n 1.4 is made on the glass. Changes of phase of $\frac{1}{2}\lambda$ occur at A and B and a change of 2 x $\frac{1}{4}\lambda$ occurs in travelling from A to B to C. Therefore the ray from C is out of phase with that from A and the total reflected energy is reduced.

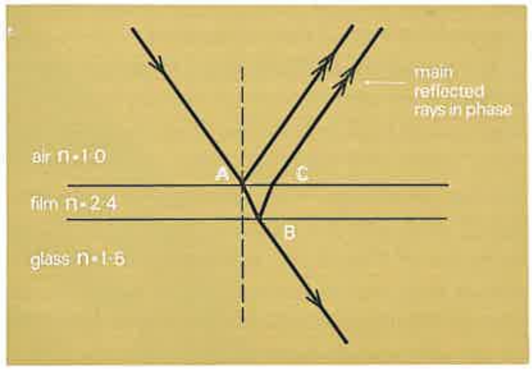


Figure 6 Here n of film is high (2.4). No change of phase occurs at B (The ray from A meets glass of lower n than film) Delay in passing from A to B to C makes the reflected rays in phase with each other, so the reflection is enhanced.

fluoride (n = 1.38) and zinc sulphide (n = 2.38) and we could expect therefore that adding one zinc sulphide layer to the glass surface would increase reflectance considerably, while a layer of magnesium fluoride would reduce the reflectance only slightly. The method is to add several layers of material of alternately high and low refractive index to a glass substrate. (Figure 7) The reflected energy from the bare glass, perpendicular to the incident light, is about 4% from each surface, totalling 8%. Adding a layer of high index material such as zinc sulphide will raise this to 35% but the next layer (magnesium fluoride) will reduce it to 19%. The next layer of zinc sulphide will bring the total to 65%; the following layer will reduce it again and so on, so that after nine layers the reflectance will have been raised to approximately 95%.

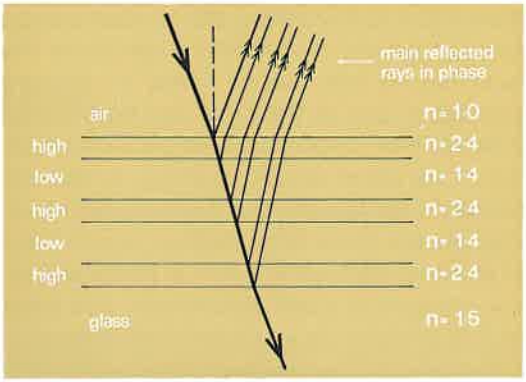


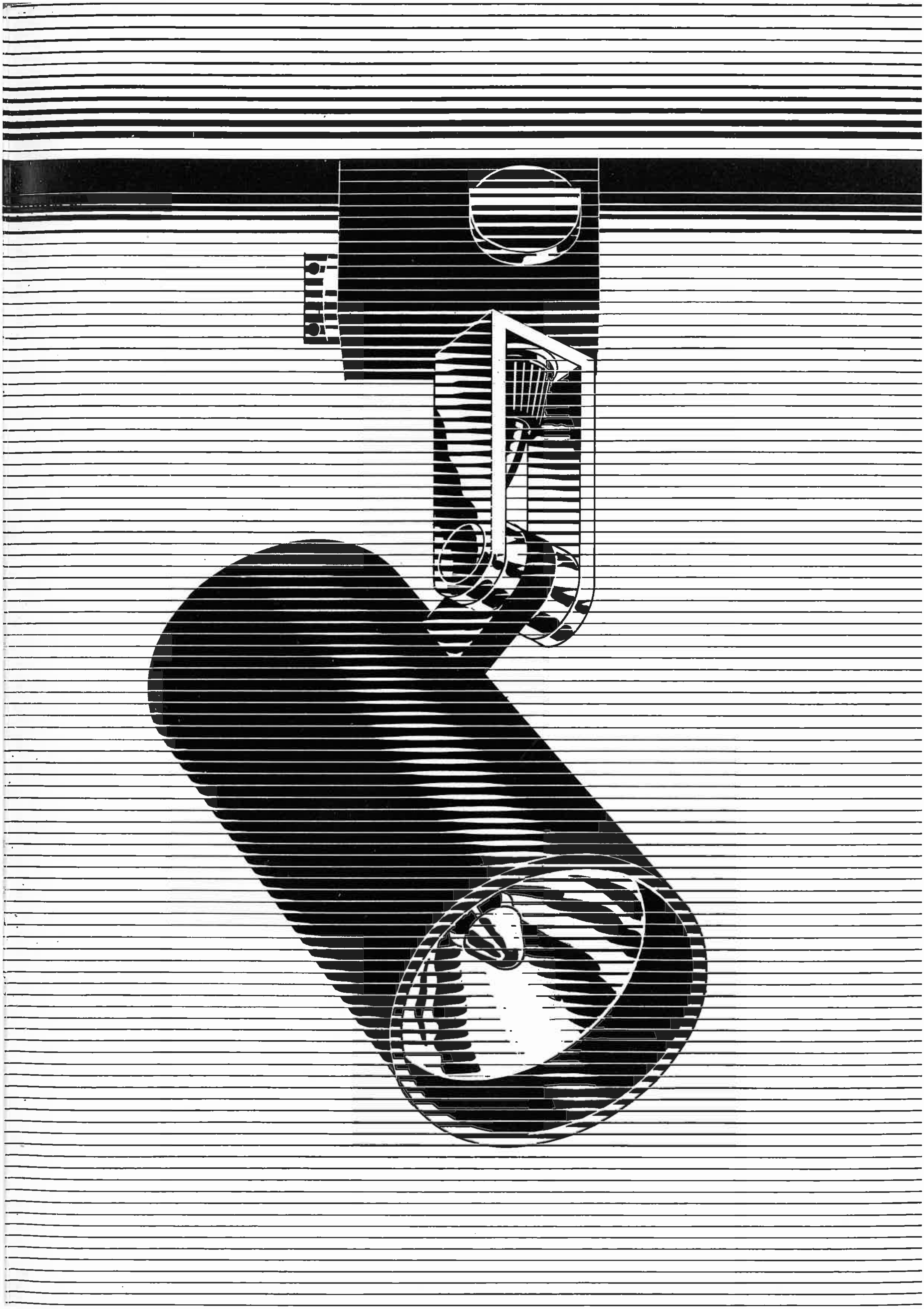
Figure 7 A five-layer stack of high and low refractive index films. If chosen $\lambda = 500$ nm, the thickness of the "high" film is just over 2 millionths of an inch; that of the "low" film is $3\frac{1}{2}$ millionths.

How different colours are reflected

It must be remembered that our layers have a thickness of one quarter wavelength, and the reflectivity values given above are related to this wavelength and a small range of wavelengths above and below this value. The visible range of wavelengths extends from about 350 to 760 nanometers ($1\text{nm} = 1 \times 10^{-9}$ metres) — from violet through blue, green, yellow and orange to red. Thus, if we choose a blue wavelength at, say, 420nm, the reflection will be effective at or near this wavelength, and other wavelengths, especially those in the red region, will not be reflected but transmitted. Similarly, if we produce a red-reflecting mirror, it will transmit blue-green light. Extending this principle further, we can produce a mirror which reflects all visible wavelengths by adding layers reflecting several different wavelengths. Such a mirror will then allow the infra-red and ultra-violet energy to pass through it and is commonly known as a cold mirror. A reflector which does the opposite is known as a hot mirror. All of these may be referred to as 'dichroic'.

Summing up, we may say that a polished metal mirror is not very discriminating as to wavelength, because, although it might have a characteristic colour, other wavelengths, including the infra-red, are reflected strongly and no energy is transmitted because the material is opaque. On the other hand, a dichroic mirror can be very selective indeed, reflecting over a very small waveband, or can cover a fair range—as the cold mirror does—while other wavelengths are transmitted rather than absorbed.

The application of these ideas to lamps has been delayed owing to the difficulty of application of the layers to the accuracy required at a reasonable cost, but methods of manufacture are now available which have made the dichroic lamp quite commonly used, especially for display purposes. The principle is usually applied to pressed-glass lamps in which the dichroic material is either applied to the reflecting surfaces of the lamp, producing a cold beam, or to the front glass where they act as colour filters, in which case the reflector is of the normal aluminised type. A still more interesting application is the use of an ellipsoidal dichroic mirror with a tungsten-halogen lamp, of which it may form an integral part of a condenser system in a cine or slide projector. The concentration of heat in the gate of the projector is much reduced, simplifying the design of the apparatus.



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