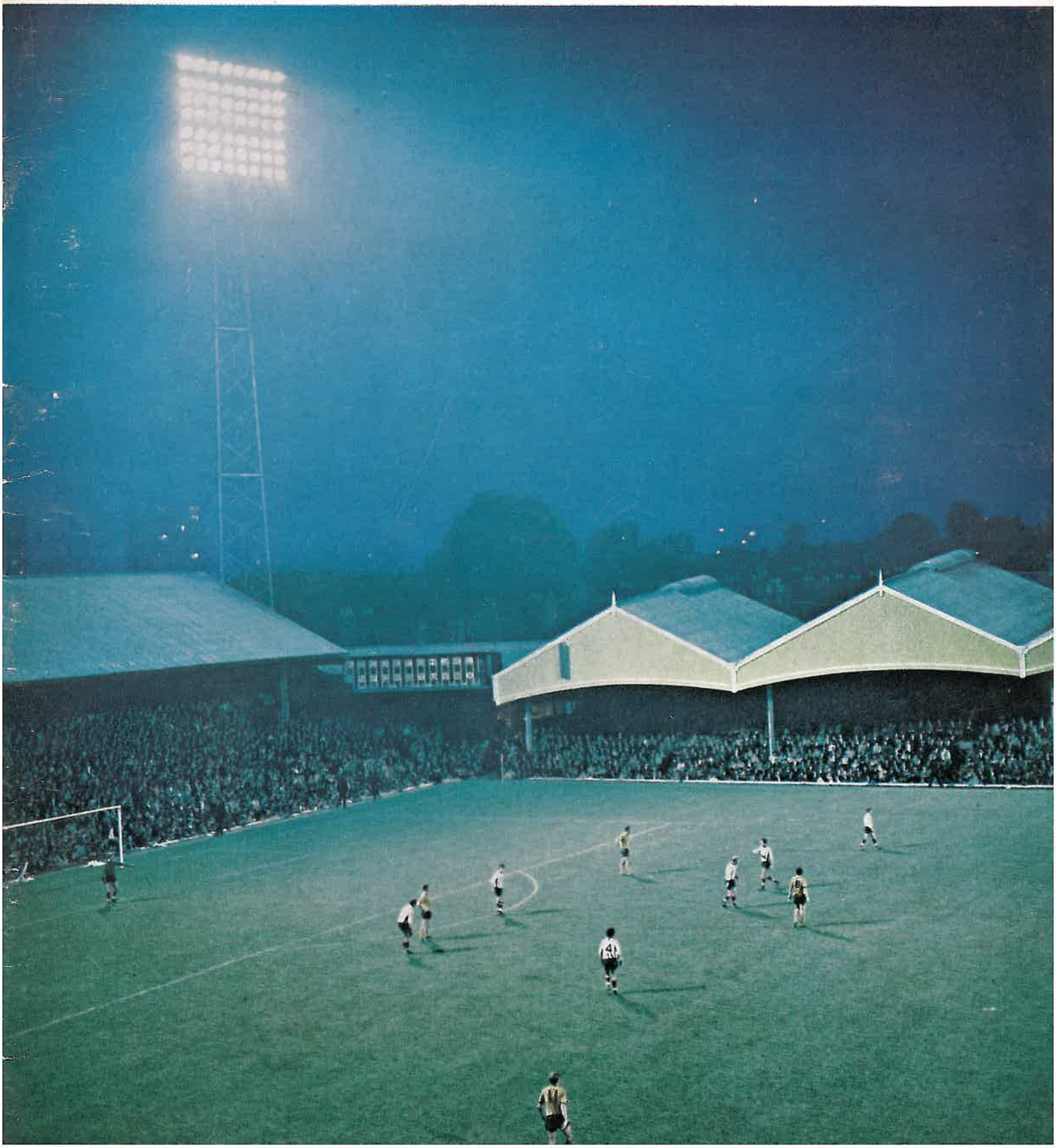
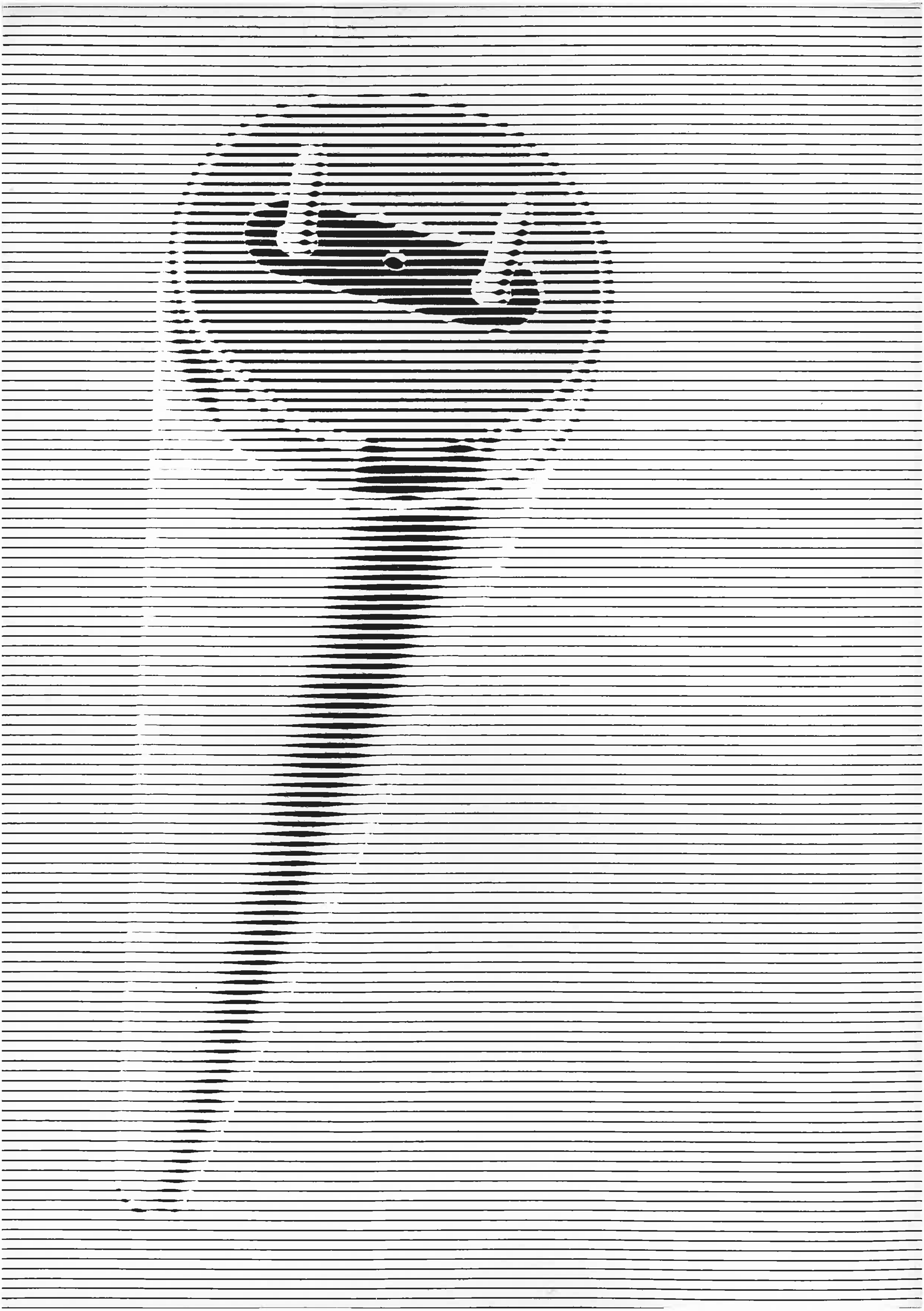
LIGHTING JOURNAL

advantages of new amalgam tube
developments in tungsten-halogen
integration in a store

number three/autumn 1969/published by THORN LIGHTING LIMITED

THORN





Lighting Journal
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Cover picture was taken at the Molineux ground of Wolverhampton Wanderers during the first football match played in Britain under permanent floodlighting with horizontal illumination averaging 700 lux. See Pages 20-21.

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In these days lighting people seem to spend a lot of time talking about heat. The heat which is an inevitable by-product of electric lighting used to be regarded as nothing but a nuisance; it was accepted as a necessary evil. More recently, however, various aspects of heat have assumed a new importance, particularly in fluorescent lighting installations.

It is well known that the tubular fluorescent lamp is temperature-sensitive, and, particularly when used in totally enclosed fittings, can lose some of its luminous efficacy unless special precautions are taken. Some few years ago we saw the production of devices such as "heat sinks" in fittings, and temperature considerations also influenced diffuser designs and lamp loadings; in fact the change in rating of the 5ft tube from 80W to 65W came about in this way.

In the meantime it became apparent that close integration of lighting and air conditioning systems could achieve a useful control of lamp temperature and also remove the unwanted heat, or even employ it in a useful way. An article in this issue of *Lighting Journal* explains how this has been done in a retail store by means of airhandling lighting fittings.

In another article, however, the author turns back to the basic problem of temperature control in orthodox types of enclosed fluorescent fittings and describes how amalgam tubes of novel design can operate efficiently at higher temperatures.

So it appears that the problem can be solved in two ways: if the air conditioning engineer does not remove the heat, the lighting man has produced a lamp which will operate efficiently at high temperatures. On the other hand, if the heat can be removed, the airhandling fitting can maintain good lighting efficiency with standard tubes. In one case the problem is solved by a lamp, and in the other case by a fitting. It is an involved business and there is little doubt that the future will hold further developments.

the new amalgam tube

by Don Hodgkiss BSc AIScB

Introduction

Before discussing the function and advantages of the amalgam tube it is useful to consider carefully those performance limitations of the standard fluorescent tube which the new design attempts to remove. The fluorescent tube is one of the most efficient light sources currently in wide use but it is well known that in order to achieve optimum performance the conditions under which it operates must be carefully controlled. One factor which markedly affects the light output of a fluorescent tube is the temperature at which it runs. In general, standard tubes run most efficiently in an ambient temperature of 20 – 25°C and in this thermal environment the tube wall will be at about 40°C. This is an accepted standard condition of use and all published photometric and electrical tube data refer to tubes run in this manner. In practice, however, tubes are very often run in enclosures, so the ambient temperature within the luminaire is considerably higher than the optimum value, with the inevitable consequence that light output is reduced.

The way in which light output varies with bulb wall temperature is shown in Figure 1. It can be seen that at temperatures around 70°C almost 30% of the potential light output has been lost; even at 60°C the loss is in excess of 20%. The gain which would be obtained if tube performance could be optimised over this high temperature range can be easily calculated from this graph and is shown in Figure 2. It should be remembered here that to a certain extent such a calculation is unrealistic since it compares existing fluorescent tubes with an imaginary ideal tube the light output of which is independent of temperature. However, the calculation is worthwhile in that it indicates the magnitude of the gain that might be achieved. Tube temperatures as high as 80°C can occur in some multi-lamp enclosed fittings and 65°C is a common value in standard enclosed fittings. It is relevant to note that with the current trend towards smaller and more completely enclosed fittings (dust-proof types) and higher room temperatures this problem is becoming ever more widespread and severe.

A further effect of an increase in temperature is that it produces a marked change in the colour appearance of the tube. For example, a

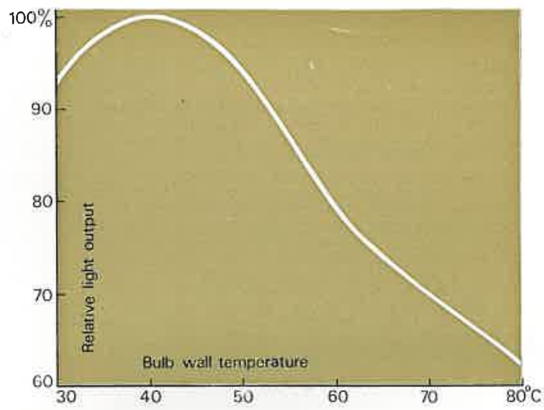


Figure 1

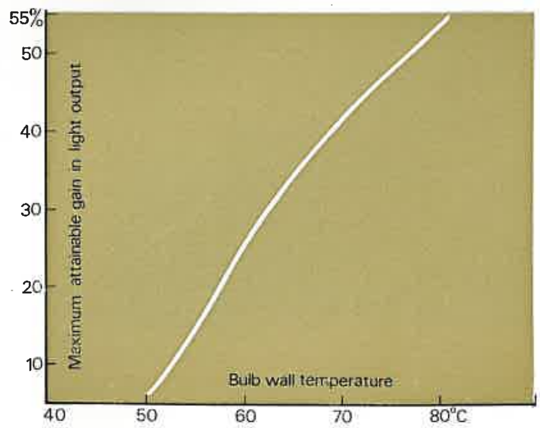
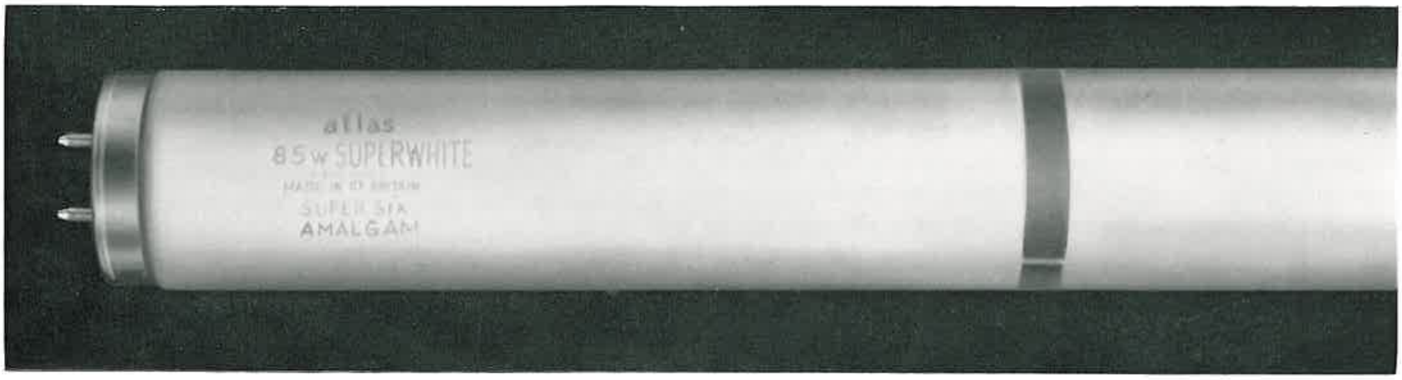


Figure 2

Warm White tube operating at 70°C bulb wall temperature will match quite closely a White tube running under the design condition of 40°C bulb wall temperature. This shift towards colder colours will occur for all colours of tube since it is due almost entirely to changes in the colour and relative luminosity of the mercury discharge itself. For example, at around 40°C bulb wall temperature the luminous flux from the mercury discharge is about 8% of the total from the lamp; at 75°C this is almost 20%. Not only does the amount of radiation from the arc increase but the relative intensities of the various spectral lines change in such a way that the resulting colour appearance of the discharge shifts markedly to the blue-green region of the spectrum.

The technical problem

The main reason for this decrease in light output and colour shift with temperature is the rise in mercury vapour pressure within the tube. Two effects occur as temperature rises: the tube runs at a lower wattage (for fixed circuit voltage) and the inherent tube efficiency



The Atlas amalgam tube

falls. This second effect is due mainly to the reduction in efficiency with which useful ultra-violet radiation is produced and to a very much smaller extent to the efficiency with which the phosphor converts this radiation into visible light. The combined result of these effects is the performance variation shown in Figure 1.

The key to the problem is control of mercury vapour pressure. Such control can be secured by arranging that somewhere within the tube there is a surface at about 40°C; if only a very small area is controlled at this temperature the mercury vapour pressure throughout the tube will stabilise at its optimum value. Several techniques have been used in the past to exploit this principle. Heat sinks have been arranged in the fitting in order to produce a cool spot on the tube wall where the sink touches it and tubes have been made with special electrode structures so that the ends of the tube run at a lower temperature. However, with the temperatures now encountered in enclosed fittings these methods are no longer very effective.

The amalgam tube

The attempts at mercury vapour pressure control mentioned above may be considered to be mechanical/physical in nature. In the tube which is the subject of this article the control system may be described as chemical/physical. Descriptions of tubes employing

Don Hodgkiss is with the Lamp Development Group of the Thorn Lighting Laboratories at Enfield.

similar systems of control have appeared in the literature [1-3] but none incorporates the same combination of features as the tube to be described.

The amalgam tube exploits the principle that the pressure of mercury vapour above an amalgam (a solution of a metal in mercury) at some particular temperature is less than it would be above pure mercury at that same temperature. By selecting an appropriate amalgam we can arrange that the mercury vapour pressure has its optimum value at whatever temperature is chosen. We have used indium as the amalgam forming metal since it can be introduced reasonably easily into the tube in the form of a ring a quarter of an inch in width deposited directly on the glass surface. (The ring also serves to distinguish amalgam tubes from standard types). Such a construction is axially symmetrical, so the tube can be operated satisfactorily no matter what angle the plane of the pins makes with the horizontal.

Technique of manufacture

This technique of manufacture involves minimum disturbance to normal production processes as the ring of metal can be applied to the tubes before the normal first stage in the lamp-making operation. The position of the ring (about 5in from the tube end) has been carefully chosen so that it is not influenced thermally by the cathode and its mean temperature is as low as possible when the tube is operating. A point at the centre of the tube would be marginally cooler but in addition to the greater difficulty in depositing the ring at this point there are aesthetic and optical objections to this central positioning. It would be possible to place the ring much closer to the cathode where it would reach a significantly higher temperature when the lamp is running but in order to keep the mercury vapour pressure low enough in this situation the indium/mercury ratio would need to be quite high, i.e. the amount of mercury would be small. This is undesirable for several reasons and the factors to be optimised will be considered later in some detail since the performance limitations which have to be overcome have led to another new design feature not yet considered. In the new tube the ratio of indium to mercury, which determines the temperature at which the optimum vapour pressure occurs, has been chosen such that the optimum value is produced at 65°C bulb wall temperature.

Tube/fitting relationship

The way in which light output varies with temperature for a typical amalgam tube is shown in Figure 3. It can be seen that what has been achieved is a transposition of standard tube behaviour to a higher temperature range. The light output is still a function of temperature but we now have the means to choose where the peak will occur. A comparison of amalgam and normal lamp performances shows that the actual amount of gain in light output will be a function of temperature. From the two curves of Figure 3 one can calculate the advantage at any temperature within the range covered and the result is shown in

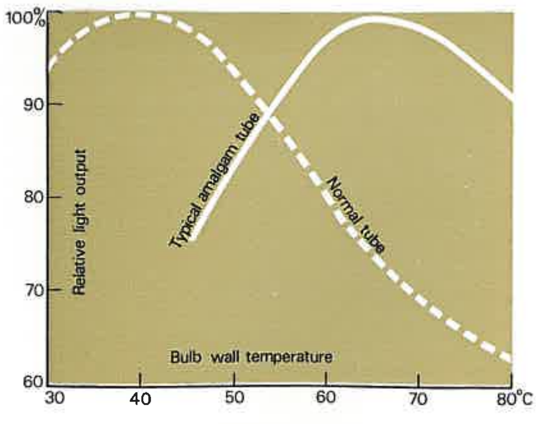


Figure 3

Figure 4. This graph demonstrates why it is difficult to quote any one figure to indicate the advantage an amalgam tube offers; it depends on how it is used, or rather how adverse are the conditions under which the normal tube (which it is to replace) is being operated. With a tube of the characteristics shown in Figure 3, light output increases of up to 20% have been achieved in standard catalogue fittings.
A further advantage is that at its optimum temperature such a tube has the same colour appearance (chromaticity) as a standard tube operating under its design conditions of 40°C bulb wall temperature and this chromaticity is that shown in the catalogue.

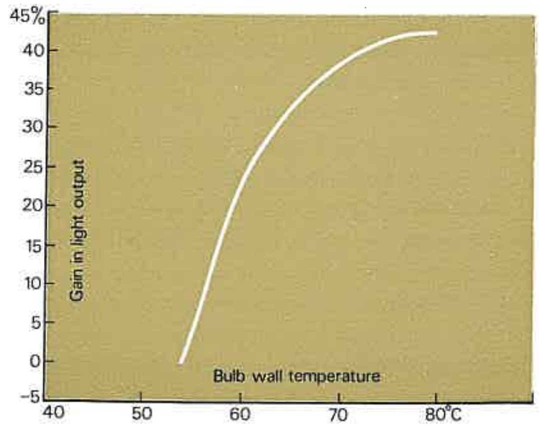


Figure 4

Light output at switch-on

So far we have considered, perhaps tacitly, the performance of the amalgam tube when it has stabilized in operation, i.e. when the tube has been running long enough for it to have reached an equilibrium condition. A parameter of considerable practical importance is the behaviour of the tube when first switched on, and in considering this we return to an earlier point concerning the ratio of indium to mercury used in the tube.
A given mercury vapour pressure above the amalgam can be obtained either with a mercury-rich amalgam running at a fairly low temperature or one relatively low in mercury concentration which is operated at a higher temperature. With a high temperature amalgam the mercury pressure at room temperature will be very low and also the amount of mercury will be very small. This is unsatisfactory for two main reasons. If the amount of mercury in a fluorescent tube is too small mercury deficiency may occur at some stage during life since there is a tendency for mercury to be 'cleaned up' during operation of the lamp. Mercury deficiency will produce low light output and ultimately premature lamp failure.
A second and equally important reason is that if an amalgam which has a high indium/mercury ratio is used the mercury vapour pressure at room temperature will be very low. This will have two effects; the possibility of poor starting and a low light output when the lamp is first switched on from cold. It is necessary to ensure that the change in amalgam temperature between the quiescent and operating conditions is kept as small as possible so that correct pressure at operating temperature becomes compatible with an adequate, though lower, pressure in the off condition. The Thorn tube, therefore, uses a mercury-rich amalgam which is so positioned in the tube that it assumes a relatively low temperature during tube operation.

Control of vapour pressure

Experience, however, has shown that even under these conditions the initial light output immediately after switch-on can be unacceptably low and its increase with time over the first few minutes of lamp operation too small. Some means have to be provided of producing an early rise in mercury vapour pressure while at the same time not allowing it to exceed the optimum value at the higher operating lamp temperatures. This has been achieved in the new tubes by arranging that each electrode is enclosed by a shield which has a thin layer of amalgam over part of its surface. When the lamp is cold mercury is distributed between these shields and the indium ring on the tube, with most of the mercury held by the ring (because it contains more indium than the shields). When the lamp is switched on these shields are heated quite rapidly and evolve sufficient mercury in the first few moments of lamp operation for an acceptably high and increasing light output to be produced. When the lamp has stabilised very little mercury is retained by these shields due to their high temperature and they play little further part in controlling the mercury vapour pressure. This is regulated in the stabilised running condition by the ring on the tube wall. When the lamp is switched off and cools down mercury returns to the shields until the original equilibrium is again achieved between ring and shields (which are again at the same temperature) and the lamp is ready to be re-lit. The variation of light output with time for the first few minutes after switch-on is shown in Figure 5 where the solid curve relates to a tube having amalgam-coated shields and the broken line to an amalgam tube with standard electrode assembly. For comparison the performance of a normal lamp is also indicated.

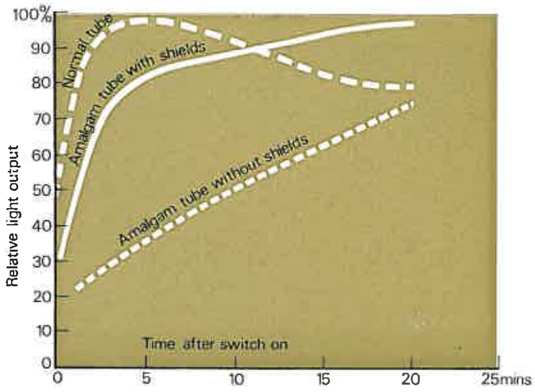


Figure 5

Compatibility

Amalgam tubes, which are available in Atlas and Mazda brands, are physically and electrically interchangeable with standard types and will operate on standard control gear.

Improvements in fitting performance

The improvement in fitting light output which the use of amalgam tubes provides is illustrated in Table 1. Here several Atlas multilamp fittings are considered and all were run in an ambient temperature of 25°C. In practice the ambient around a fitting may be higher than this so even greater gains may be achieved. The tubes used are all 6ft 85W.

2 tubes		3 tubes		4 tubes	
Atlas cat. no.	gain	Atlas cat. no.	gain	Atlas cat. no.	gain
SMD 2685	18%	SMD 3685	15%	SMD 4685	18%
TMP 2685	14%	TMP 3685	15%	TMP 4685	19%
SMP 2685	18%	TMD 3685	15%	TMD 4685	19%
SMO 2685	18%	SMO 3685	15%	FMD 4685	19%

Table 1

The table shows data for the Atlas Format range fittings. Improvements will be obtained in other types where the tube ambient is higher than optimum; for example, in the Atlas Sentinel PPU/Q2685 a gain of 20% has been obtained.

An installation at Thorn House has been fitted with amalgam tubes and an improvement of more than 20% in illumination on the working plane has been achieved.

It should be noted here that the amalgam tube will run at its design rating in a high temperature environment and not under-run as would a standard tube under similar conditions. For example, at 65°C a normal 6ft 85W tube will under-run by about 12% whereas the amalgam tube will operate at design loading. Under such conditions an improvement of 25% in light output would be achieved.

Economic advantages in practice

The amalgam tube is obviously a more costly lamp to produce and the price differential of only 20% between it and a normal tube is surprisingly low. It has been made possible only by close attention to design so that a tube amenable to production on high-speed machinery has been evolved. At this price premium considerable savings can be achieved in practice. For example, in a new installation of enclosed multilamp fittings in heated interiors the use of amalgam tubes would add only 1 to 2% to the total initial cost but provide up to 25% more light. For an existing installation of this type replacement of normal tubes by amalgam types is by far the cheapest and least troublesome way of getting a similar increase in light output. No rewiring is necessary and no new fittings need be bought; the only operation is tube changing.

Future fittings design

The present tendency towards the use of smaller fittings is limited in some cases by the reduction in tube light output which occurs in the hotter enclosures produced. The amalgam tube removes this limitation and permits optimum lamp performance to be obtained in very compact fittings. This produces several potential advantages:

(a) aesthetically attractive compact fittings can become significantly more efficient;

(b) fittings can be made dustproof and so easier and cheaper to maintain;

(c) an appreciable saving in fittings cost (particularly in relatively expensive diffuser material) is possible.

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1 Evans, George S and Snyder, Paul E. Performance Characteristics of Fluorescent Lamps utilizing amalgam control of mercury vapour pressure. *Ill. Eng. 61* No. 1 (Jan. 1966) pp 51-57.

2 Bernier C J and Heffernan J C. Design and Application of New High-Temperature Fluorescent Lamps. *Ill. Eng. 59* No. 12 (Dec. 1964) pp 801-807.

3 Eckhardt K. Neue Leuchtstofflampen mit höheren Lichtstrom bei Betrieb in geschlossenen Leuchten. *Lichttechnik 17* No. 1 (1965) p 5A.

integrated services in a Boots store

by Richard W Shaw

The central area of Sunderland is being completely redeveloped as a shopping precinct, and it is here that Boots Pure Drug Co Limited has recently opened one of its latest 9 000 sq ft retail stores, taking the opportunity to incorporate into the design some of the more modern marketing techniques both in store layout and merchandising presentation and also in lighting, air conditioning and heating.

The Retail Engineering Department of Boots had many full discussions concerning the introduction of new ideas which would link closely the lighting and air conditioning systems. The Thorn-Benham Environmental Unit was pleased to co-operate in these discussions and quite early in the considerations it seemed that there was a case for integration of lighting and air conditioning, especially when it was realised that a saving of 12—15% could be effected in the cost of mechanical services equipment, plus substantial savings in running costs.

The design conditions for the sales area laid down by Boots were: internal condition 70°F dry bulb/60°F wet bulb when the external conditions are 76°F dry bulb/66°F wet bulb. Internal temperature will rise with ambient above these conditions. The installation now in operation will adequately meet these demands.

The 96 Atlas recessed modular lighting fittings were specially designed for continuous mounting, each fitting having three 8ft 85W fluorescent tubes. The lighting level planned was 1 400 lux using Warm White tubes. The diffusers used were manufactured from prismatic polystyrene sheet, and the fittings themselves are supported on the suspended Burgess ceiling grid. The ceiling acts as a negative pressure plenum. The extracted air flows through a slot at each end of the fitting, passes round the tubes and is extracted into the plenum where the ductwork collects this warm air and carries it to the stock room supply fan for introduction into the 6 200 sq ft stock room area for heating purposes when required.

At the entrance to the store nine 125W Mazda Kolorlux lamps in recessed fittings provide an interesting effect.

The following is a general description of the air conditioning system. Fresh air is drawn into the system via an external louvre and passes through a motorised damper which has a 20% fixed fresh air section. This damper operates in conjunction with the dampers on the recirculation system, under the dictates of the thermostats in the sales area, and controls the proportion of fresh and recirculated air entering the system.

The mixed air then enters the airhandling unit and passes through a filter, heater battery, cooler battery and twin centrifugal fans driven by

This project was planned in association with R E Doone CEng MIMechE MIllumES AMBIM Chief Engineer (Retail), Boots Pure Drug Co Limited

Richard W Shaw is Commercial Manager, Thorn-Benham Environmental Unit.


Lanolin Cream
Lanolin Cream
Lanolin Cream

one common motor and enters the sales area as conditioned air dependent on the conditions sensed by the room thermostats.
On leaving the airhandling unit the air is passed through a system of sheet steel ductwork and is distributed throughout the ground floor sales area via thirteen 24in × 24in ceiling diffusers.
Part of this air is extracted through seven 24in × 24in ceiling mounted extract diffusers and is ducted to the recirculation fan in the plant room. On leaving the recirculation fan the air passes through motorised modulating dampers which control, under the demands of the sales area thermostats, the amount of air returned to the system or discharged to waste through the turret on the roof.
The remainder of the air from the sales area is extracted through the light fittings into the return air plenum.
The performance requirements for each airhandling lighting fitting were that each fitting was required to handle 40cfm at a minimum resistance of .015 in wg and should have a minimum heat extraction of 65%. (Figure 1 gives test data for the lighting fitting.) A short length of ductwork in the plenum then collects the air and carries it to the stock room supply fan, after which it can either be discharged to atmosphere or fed into the stock room via the supply duct. A heater battery mounted in this duct can add heat to the air if the heat collected from the light fittings is insufficient to satisfy the heating requirements in the stock room.
Control of the stock room is by means of two averaging thermostats mounted in the space in conjunction with a two-stage control panel. On demand for heating the damper motor operates to increase the flow of warm air extracted from the ground floor lighting fittings into the stock area. When this damper is fully open and a demand for heating still exists, the booster heater motorised valve begins to open and increases the flow of hot water through the heater battery.

Heating

The water in the system is raised to a temperature of 180°F in the boiler and accelerated through the system by a pump with a maximum head of 9ft whilst passing 69 galls/min. This water serves two heater batteries, six floor-mounted fan convectors and nine ceiling mounted fan convectors. The water has a temperature drop of 20°F through the system. The fan convectors are thermostatically controlled for winter operation.

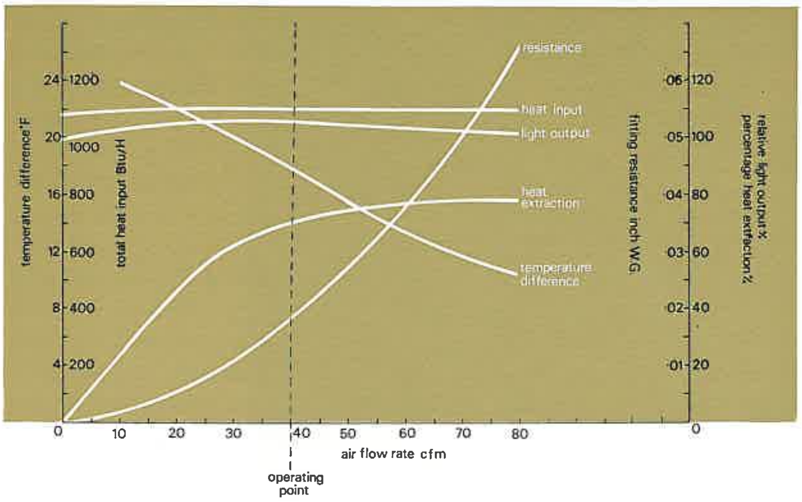


Figure 1 Performance data for lighting fitting.

Acknowledgements
The architect was Mr I V Mitchell ARIBA, Chief Architect, Boots Pure Drug Co Limited, in conjunction with Ian Fraser Associates, Manchester, and the main contractor was Gilbert Ash. The electrical contractor was Humber Electrical Co Limited. Air-conditioning and heating by Benham & Sons Limited. Lighting by Thorn Lighting Limited.

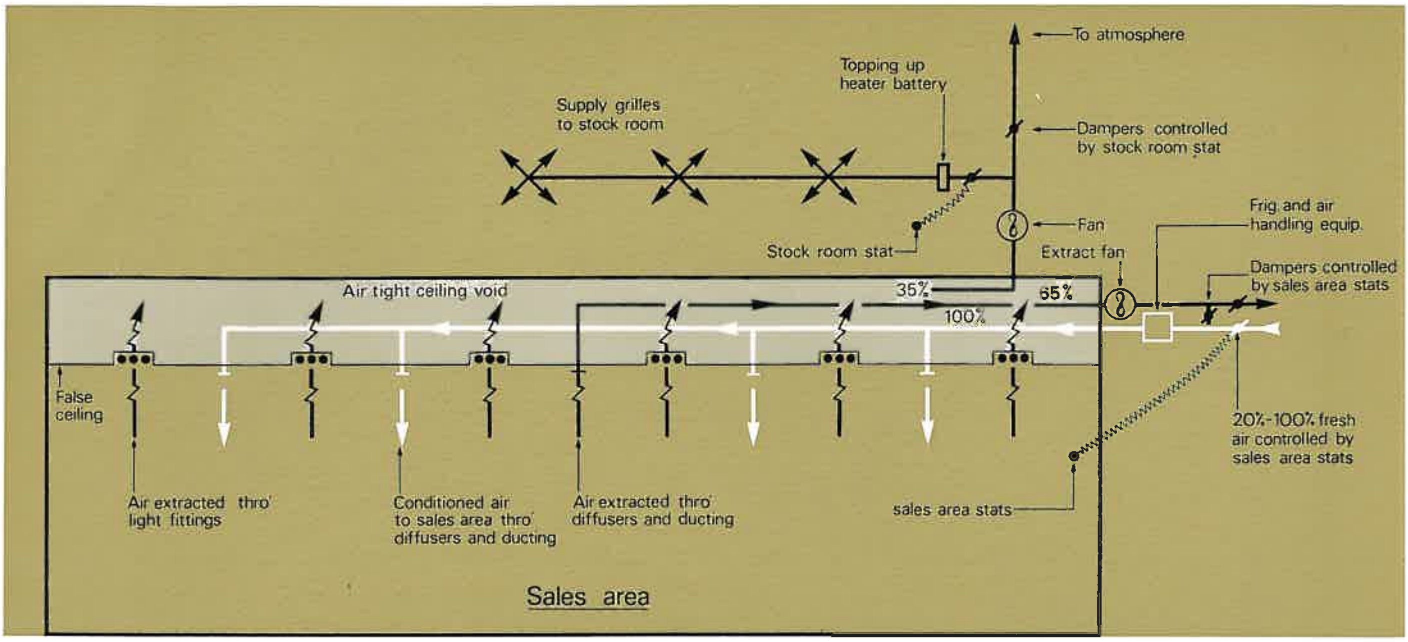


Figure 2 Schematic diagram of system

Summary of heat gains

	Btu/hr
Structural	5 320
Lighting – display	41 700
ceiling	39 200
Occupants	100 000
	186 220
5% motor and duct gains	9 310
	195 530
Latent load (maintaining the correct relative humidity in the occupied space)	91 000
	286 530

Winter heating design temperatures

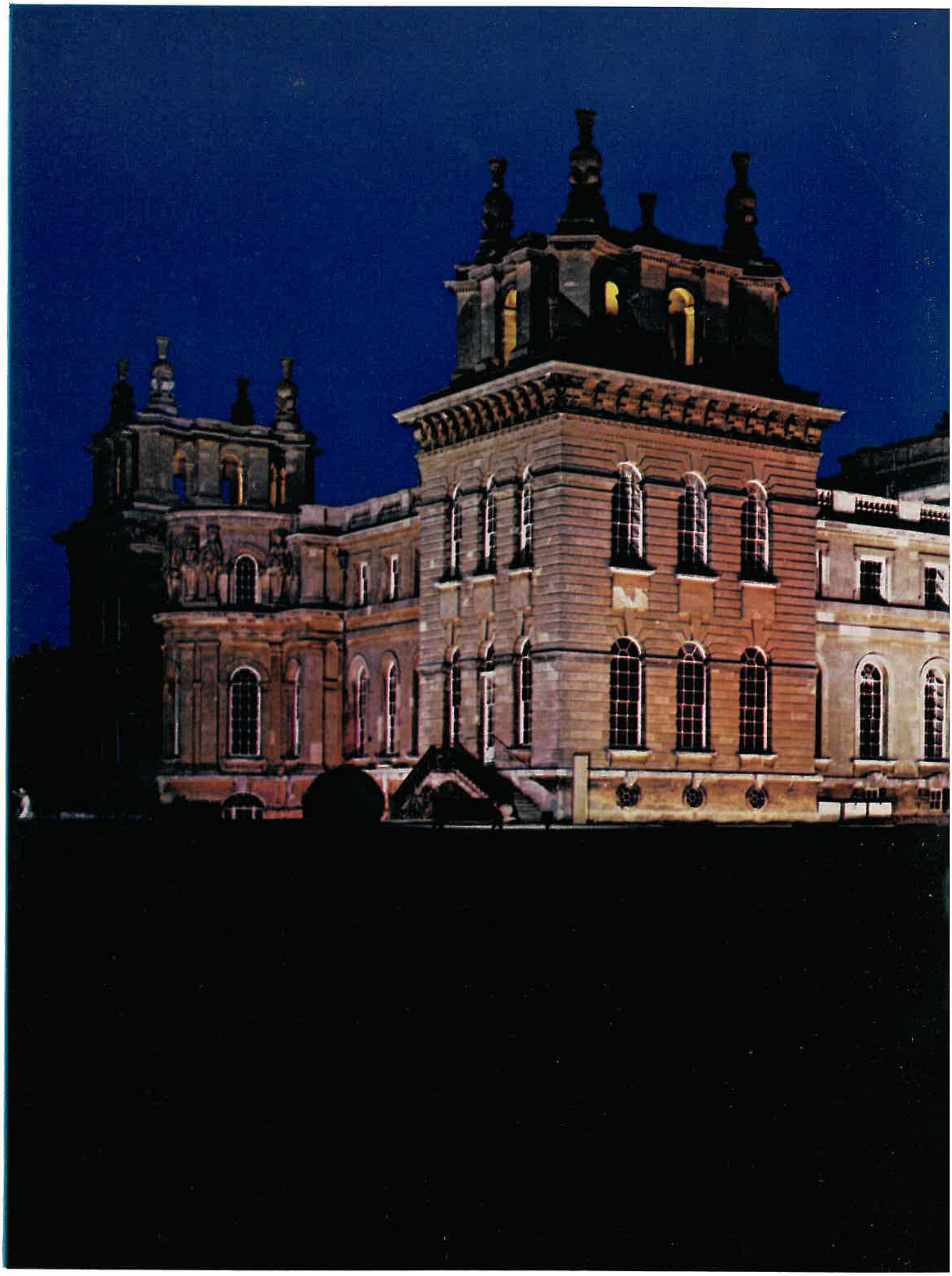
The heating system has been designed to maintain the building at the following temperatures, with an outside design temperature of 30°F:

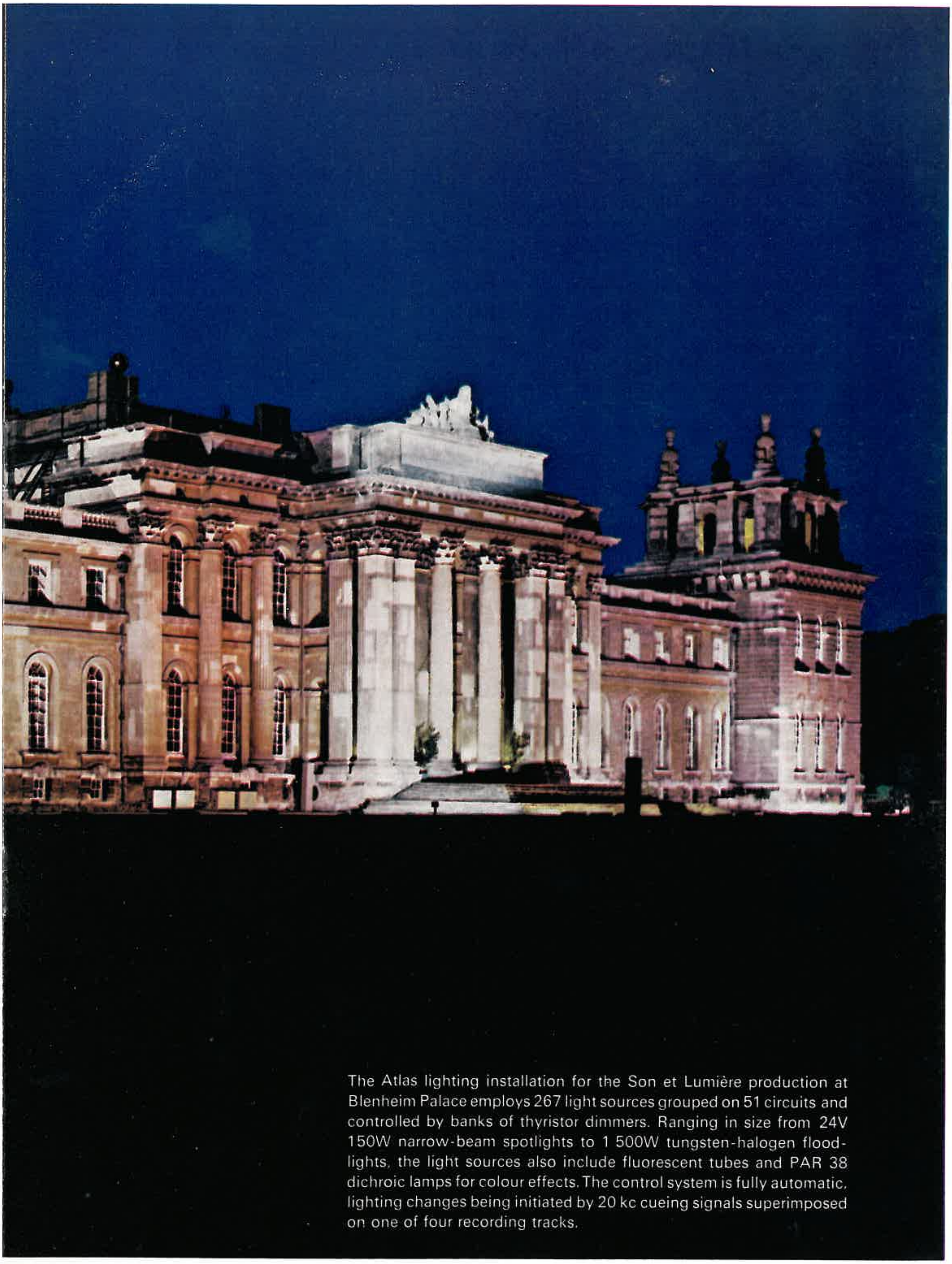
Ground floor sales	70°F
Staff areas	70°F
Stock room	62°F

Summary of heat loads

	Btu/hr
Entrance heating – 5 units at 42 000 Btu each	210 000
Entrance heating – 2 units at 17 000 Btu each	34 000
Main A/C plant heater battery	256 000
Stock room convector units	51 000
Stock room heater battery	123 000
Staff area radiators	128 000
	802 000
Boiler margin	108 000
Boiler load	910 000

Part of the plant room





The Atlas lighting installation for the Son et Lumière production at Blenheim Palace employs 267 light sources grouped on 51 circuits and controlled by banks of thyristor dimmers. Ranging in size from 24V 150W narrow-beam spotlights to 1 500W tungsten-halogen floodlights, the light sources also include fluorescent tubes and PAR 38 dichroic lamps for colour effects. The control system is fully automatic, lighting changes being initiated by 20 kc cueing signals superimposed on one of four recording tracks.

tungsten-halogen lamp development

by A Halberstadt

It is almost 90 years since Swan in this country made the first incandescent filament lamp consisting of a carbon wire in an evacuated bottle. This lamp operated at a luminous efficacy of only a few lumens per watt, producing a very yellow light. As the glowing wire was in vacuum the bulb wall was soon blackened by a vaporized layer of carbon deposit.

Since those early days scientists and engineers have striven to increase the efficacy of the incandescent lamp to produce the highest light output for a designed economic life. At the same time they have endeavoured to reduce the evaporation from the filament in order to achieve the best lumen maintenance through life.

The carbon filament was followed by the more ductile tungsten filament, which could be wound into a close coil and operated at a higher temperature. This in turn was followed by the gas-filled lamp which allowed the efficacy to be raised again without increase in evaporation: finally, in the mid-thirties, the compact coiled-coil filament was evolved. The compactness of the coil ensured maximum light density with minimum cooling effect from the gas convection streams, thus increasing the benefit of gas filling. At this stage the development of lamp technology virtually came to a halt except for progress in the mechanisation of production. Perhaps it was thought that the ultimate performance had been reached, or perhaps the emergence of mercury discharge lamps at that time meant that efforts were diverted from improving the incandescent lamp.

The action of halogens

Some ten years ago attention was once again brought to bear on the performance of the incandescent lamp. Early patents published as long ago as the beginning of this century showed that a chemical reaction between a halogen and tungsten could take place in a lamp, transferring evaporated tungsten back to the filament. However, lack of effort, lack of proper understanding of the chemical mechanism involved, and non-availability of necessary materials had prevented progress towards practical lamps.

In about 1959 it was found that by adding a halogen such as iodine to the gas filling of a specially designed lamp—with only tungsten components within the envelope and with the bulb wall temperature kept above 250°C—a regenerative cycle could be achieved. Tungsten atoms (W) evaporate from the filament through the inert argon or nitrogen gas stream. (See Figure 1). The filament normally operates at a temperature between 2 600°C and 3 200°C, the temperature being dependent on desired life and applied voltage conditions. This temperature is higher than any other artificial heat ordinarily encountered by man, a temperature at which fire-brick and asbestos melt like wax. When the tungsten atoms arrive near or on the bulb wall each atom chemically combines with two atoms of iodine to form tungsten iodide, WI_2. Thus if the bulb wall temperature is kept above 250°C tungsten iodide cannot condense on the bulb wall and tends to drift back towards the filament. When tungsten iodide exceeds a temperature of about 1 500°C near the filament it decomposes, tungsten depositing on the filament and iodine back towards the bulb wall ready to recommence the cycle. The tungsten which is returned to the

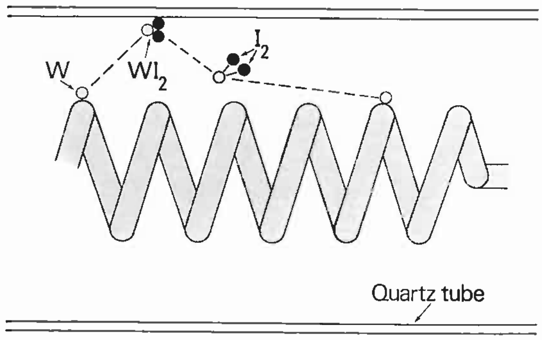


Figure 1

A Halberstadt is Manager of Tungsten-Halogen Lamp Development and Engineering in the Thorn Lighting Laboratories at Enfield.

filament preferentially seeks the cool spots of the filament, reinforcing the cooler supported areas; thus the hot spots thin more rapidly and ultimately lamp failure takes place. During the useful life of the iodine lamp, however, 100% lumen maintenance is achieved by thus preventing bulb blackening.
More recently experimental work on lamps filled with the dangerous corrosive fluorine halogen have been experimentally made; here decomposition occurs at much higher temperatures, thus redepositing tungsten on the thinner hot spots of the filament, thereby, in theory at least, producing a lamp with an infinite life. Complications in producing a fluorine lamp are so great, however, that practical lamps are unlikely to materialize.
To achieve the necessary high wall temperature the lamp has to be reduced in volume very considerably. The bulb wall, of course, keeps a constant temperature throughout life as no increased heat absorption takes place due to blackening. The material chosen for the bulb is quartz, which has a softening temperature about 1 000°C higher than the glass used for conventional lamps. A material made from natural quartz crystals, mined in Brazil, is shipped to the tube manufacturers. Here it is cleaned, electronically heated in vacuum to drive out gases and impurities, and formed into billets. The billets are heated again at a temperature approaching 2 000°C in another furnace constructed from tungsten and molybdenum and is then drawn into tubing, a costly and complicated raw material process making quartz very expensive when compared with ordinary glass. Quartz has also very little thermal expansion as compared with glass; whereas ordinary glass would shatter if heated and then quenched in cold water, quartz can withstand such harsh treatment.

Improvements in average life

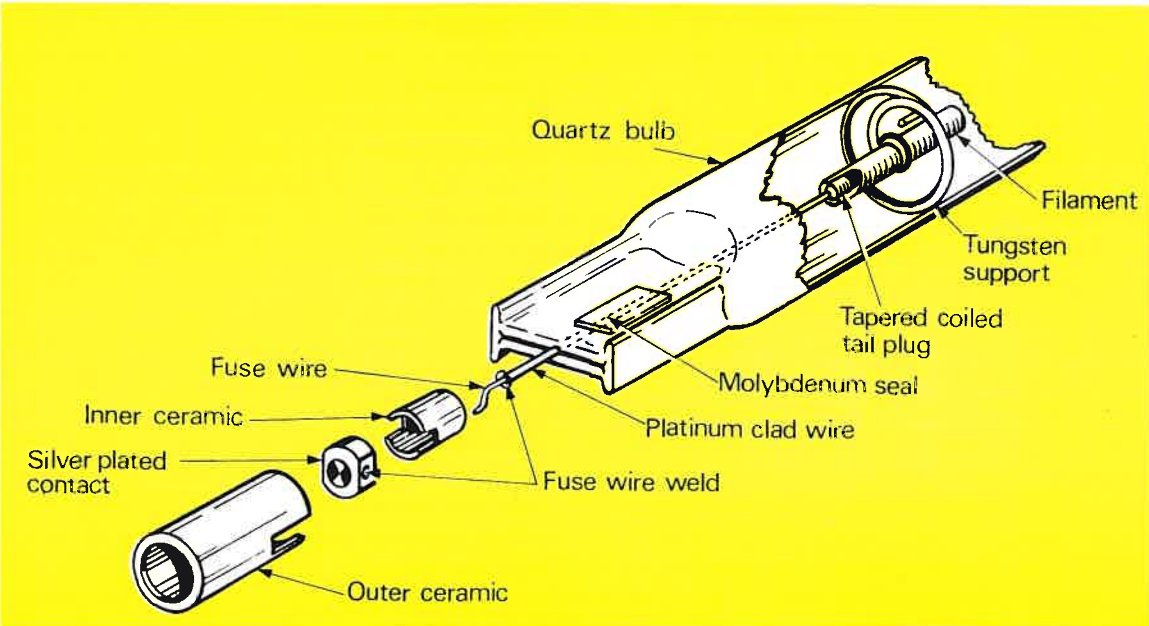
The iodine cycle described above provides a great step forward in lumen maintenance; but the tungsten-halogen lamp also offers increased life. Once the bulb volume has been reduced (sometimes by up to 200 times) the lamp becomes mechanically immensely strong. Thus the gas pressure within the lamp can be increased from below atmospheric pressure, as obtains in conventional lamps, to a pressure of four or five atmospheres at room temperature. Obviously, during actual lamp operation this is increased again by a factor of three or four. This additional pressure further reduces tungsten evaporation by holding the cloud of tungsten vapour (which exists around all lighted filaments) very tightly against the wire and reducing the number of atoms which penetrate through the gas to the bulb wall and which are therefore not returned to that part of the filament from which they originate.
With conventional lamps the gas acts as a coolant to the filament; this reduces the efficacy, but minimises blackening of the bulb. The cooling is mainly caused by the streams of gas convecting and swirling around the bulb. A hot body like a filament holds a stationary layer of gas in close proximity to itself and the freely convecting gas is always measurably distant from the filament. Thus in the case of many tubular halogen lamps there is no convected cooling of the filament because this "Langmuir sheath" covers the whole internal diameter of the bulb.
In tungsten-halogen lamps, therefore, it is possible to achieve longer life or increased light output or a combination of the two. The magnitude of the gain varies from type to type, but may be expressed as approximately double life with an increase of 30% in efficacy. For example, a 1 500W lamp is increased in life from 1 000 to 2 000 hours

and the efficacy raised from 17 lumens per watt to 22 lumens per watt with a colour temperature increase of about 150°K.
The dramatic reduction in the size of the lamp means that much better use can be made of the light produced. A reflector can be placed in close proximity to the filament and even if small it can collect light through a large angle. This leads to a considerable reduction in fitting size, fitting cost and installation cost. For example, an older floodlight fitting might weigh 25lb whereas a comparable tungsten-halogen fitting may weigh only seven or eight lb.

Summary of advantages

The advantages of halogen lamps, compared with conventional lamps, can be summarised as follows:
(1) 100% lumen maintenance;
(2) Increase in life and/or luminous efficacy;
(3) Improvement in optical performance of fitting or optical system;
(4) Reduction in fitting size and cost.
There are four halogens: iodine, bromine, chlorine and fluorine. Iodine, which is distinguishable by its pink afterglow, is mainly used in lamps of long life and relatively modest rate of tungsten evaporation. In short life sources, such as photographic and automobile lamps operating at a high filament temperature, considerable quantities of iodine are needed in the lamp to take care of the rapid tungsten evaporation, and oxygen is also added to speed up the cycle. The heavy dose of iodine acts as a colour filter, reducing efficacy and giving a pinkish cast which is objectionable for photographic purposes.
It was found that bromine, which is a clear gas, does not introduce colour absorption, but on the other hand it is corrosive and it readily attacks and thins the cooler section of the filament. The breakthrough came recently when compounds were introduced, such as hydrogen bromide (HBr) and methylene bromide (Ch_2 Br_2), a combination of hydrogen and bromine and of carbon, hydrogen and bromine respectively. These compounds dissociate in the hot areas of the lamp, allowing free bromine to do its work of returning evaporated tungsten. However, in the cooler areas, e.g. in the vicinity of the filament tails, the relatively inert compound remains associated and therefore does not attack the wire.

Figure 2 Cap and seal of the linear tungsten-halogen lamp



The use of these halogen compounds for long life lamps is not possible because hot quartz is pervious to hydrogen and when the compound is dissociated some of the hydrogen manages to escape through the quartz bulb leaving free bromine which can attack the cooler portions of the filament. Bromine compound lamps are therefore limited at present to lamps of less than 1 000 hours life.

Manufacturing techniques

So far two families of basic lamp designs have been developed: single-ended lamps where both conductors are embedded in the seal at one end and double-ended linear lamps where there is one conductor in the seal at each end. It is the design of the linear lamps which deserves some further mention as they are finding increasing use in floodlight fittings such as the new range of Atlas Haline fittings. Manufacturing techniques for tungsten-halogen linear lamps are, of course, more complex than for the conventional lamp. For instance, the impurities within the tungsten wire must be carefully controlled. Heat treatment of the filament must ensure that the crystal structure is so arranged that when the filament is alight practically no sag takes place, as this could cause the filament to touch the bulb and result in failure. A special problem lies in the design of the quartz pinch seal and ceramic end cap.

Quartz, as stated earlier, has very little expansion when heated, compared with metals, and the types of glass-to-metal seal used in other lamps are not possible in a halogen lamp. The glass and metal must have similar expansions so that when they are heated and cooled they will expand and contract together and therefore not tear apart and crack. At the same time, the metal in the seal has to withstand 2 000°C during the quartz heating operation, thus ruling out all the metals which have a lower melting temperature.

The technique at present in use in halogen linear lamps is to use a very thin molybdenum foil. In the centre it is just over one thousandth of an inch thick, tapering to one tenth of this thickness near the edge. This foil is then sandwiched in the quartz pinch under tension and, because of its small cross-section, has elastic properties and will not tear itself from the quartz and break the seal. (See Figure 2). This form of seal is restricted by the current it can pass without loss of watts. More important, molybdenum oxidises at temperatures above 350°C. Oxygen from the atmosphere will oxidise and break down the seal in under 50 hours where the temperature exceeds 450°C. Protecting substances such as platinum or filler glasses which prevent air from penetrating to the molybdenum are in use but they have their limitations. For long life linear lamps of 2 000 hours the only certain way of ensuring a satisfactory seal is to keep the temperature below 350°C, and this can be done by conducting the heat to the casting of the fitting by means of heat sinks. Figure 2 also shows the fuse incorporated in the ceramic cap of these lamps to prevent violent arcing at the end of lamp life.

Range of linear lamps

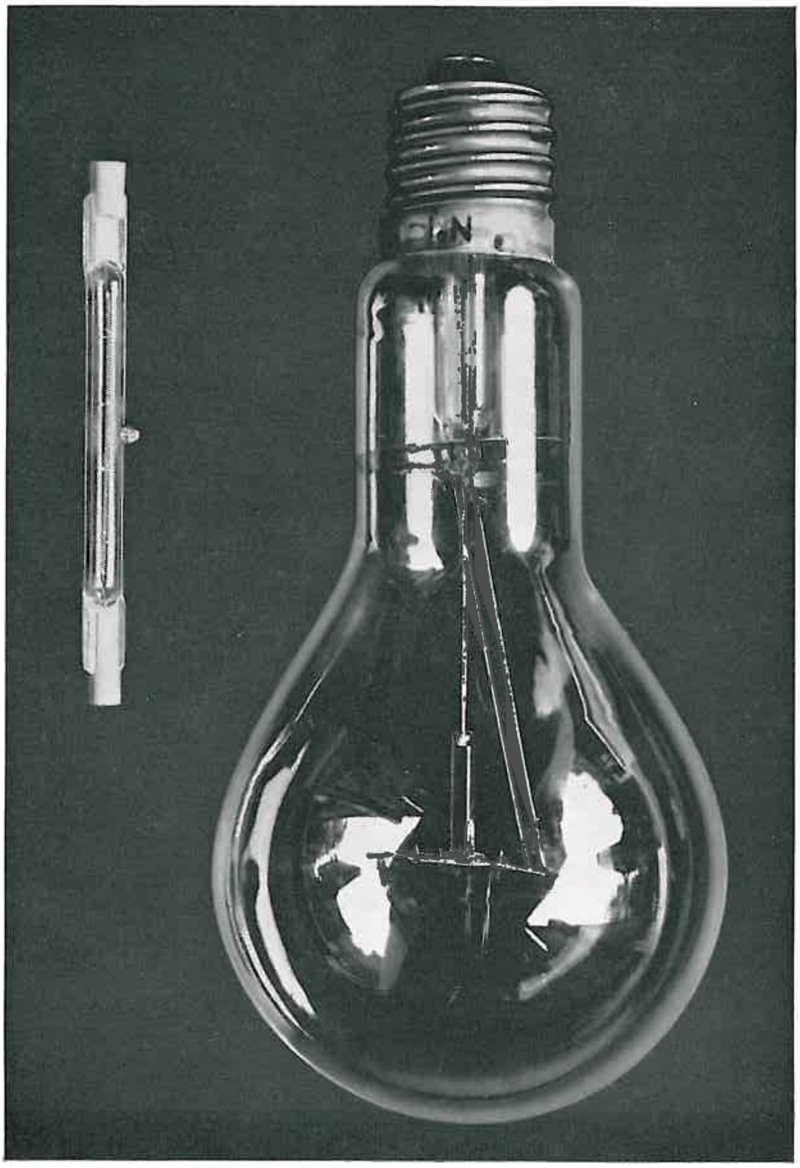
The range of linear double-ended floodlight lamps so far developed are all designed for a nominal life of 2 000 hours, which is double the life of conventional lamps. Their diameter is only 10mm and the length varies with the wattage rating. Thus the 2 000W lamp is 330mm long and this is the lamp of the highest light output; the lowest rating is the 500W lamp, only 117mm long. Within this range there are three other ratings of 1 500W, 1 000W and 750W.

Figure 3 shows the 500W lamp, a product unique to Thorn Lighting. The lamp has already been well proved in the Sunflood fitting. The illustration shows it in comparison with a conventional lamp. Whereas all the other four ratings have a single coil filament using a spacer as shown in Figure 2, this was not possible in the case of the 500W lamp. The lower wattage required a much longer filament of considerably reduced diameter, and a coiled coil filament was developed, using spacers interwoven into the turns of the primary winding. This, combined with a specially selected wire and tightly controlled heat treatment of the coil, made a robust construction possible.

The future will no doubt always have a requirement for these double-ended lamps, which are ideally suitable for floodlight and general illumination purposes. Development efforts are therefore at present directed in two ways to improve these lamps. Firstly, the limitation on seal temperature of 350°C only achievable at present with heat sinks should be overcome. This may require new sealing technology and more sophisticated materials which do not readily oxidise as do molybdenum and tungsten at lamp operating temperatures.

The second area of improvement will be directed at producing more lumens for the same life. This means a higher filament operating temperature. As mentioned earlier, fluorine may be an answer but the use of gases and vapours of heavier atomic weight which retard evaporation may help to achieve these aims.

Figure 3 Two 500W Mazda lamps: the linear tungsten-halogen lamp compared with the GLS lamp.



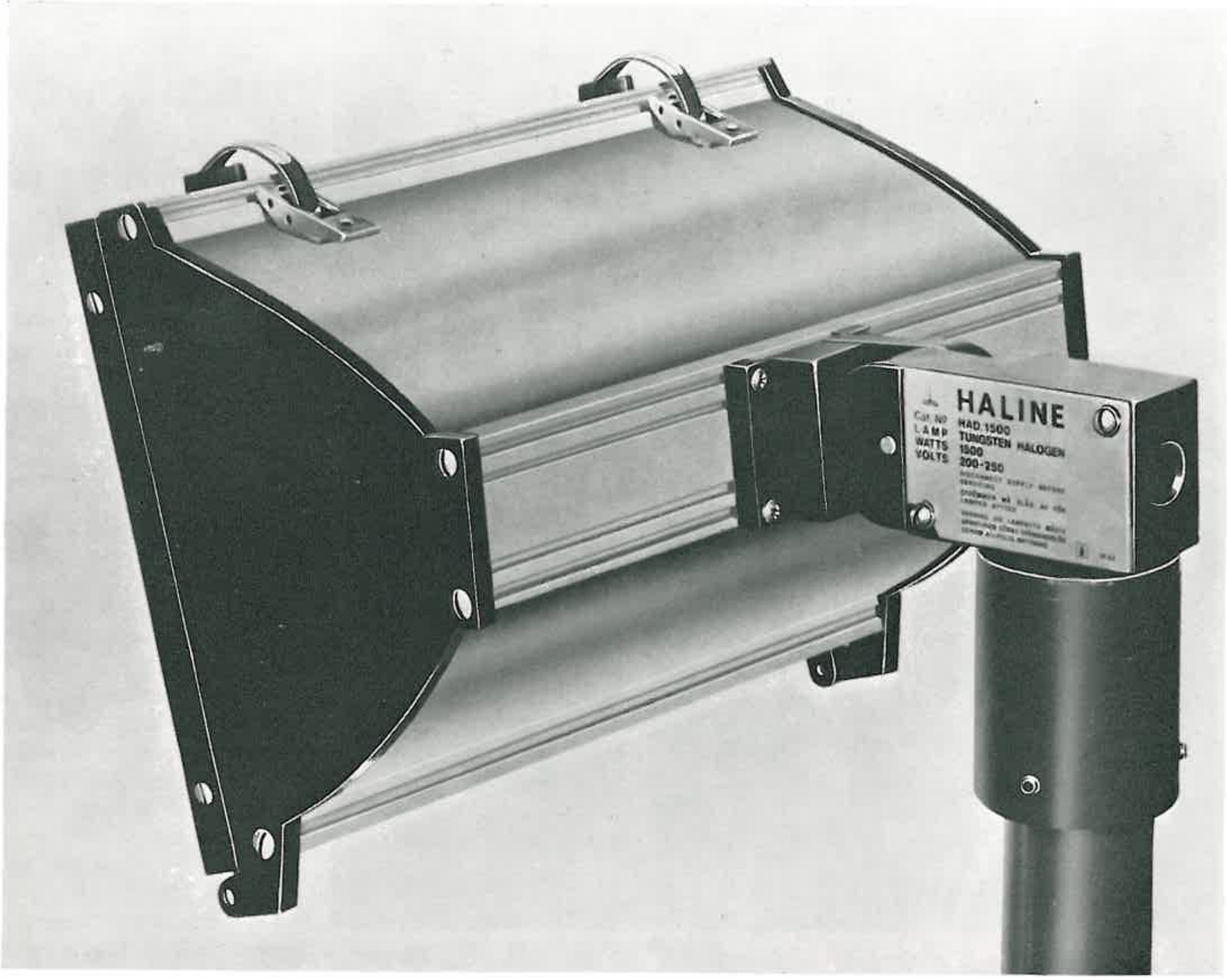


Figure 4 The Atlas Haline floodlight

The Atlas Haline range

The Atlas Haline range of floodlight fittings, with sizes from 500W to 2 000W, is the latest example of equipment specifically designed to gain maximum advantage from the linear, small cross-section lamp. These fittings are compact and light in weight, and accurate light control is assured by the use of an extruded body/reflector section. (See Figure 4).

Reflectors give asymmetric light distribution in the vertical plane where the small cross-section of the lamp permits precise optical control.

Horizontal light distribution is wide, fan shaped, deriving from the long lamp with correctly positioned end reflector diaphragms. (See Figure 5).

The high operating temperature of the tungsten-halogen lamp brings problems in small, compact fittings. Materials have been carefully selected in the Haline range which will withstand high operating temperatures for a normal life expectancy, and rigorous testing has been applied at all stages of development.

Only by the adoption of careful design and testing can the potential advantages of the linear lamp be fully realised, and the Haline range has been made possible only by the full co-operation of lamp engineers and fitting designers at all stages.

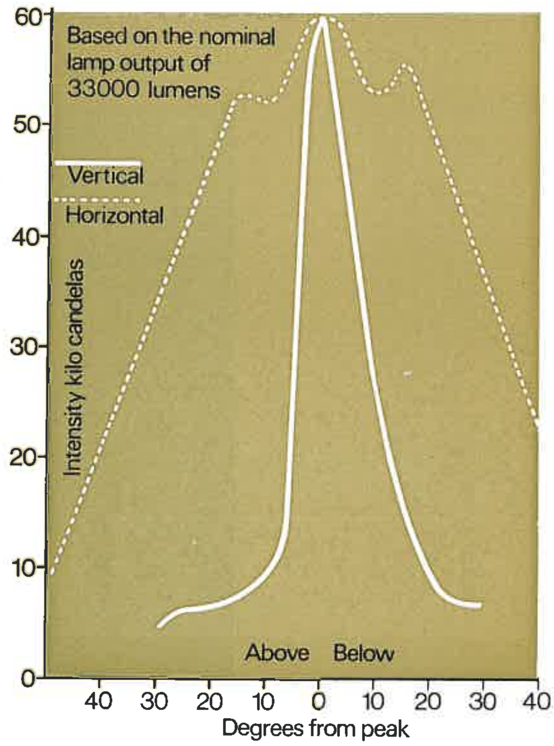


Figure 5 Typical light distributions

Floodlit Molineux from one of the four 45m towers. The game was specially recorded by Thames TV in preparation for the introduction of all-channel colour television.

floodlighting at Molineux Park

The recently completed floodlighting installation at Molineux Park, home of Wolverhampton Wanderers Football Club, represents the first step in satisfying the demands for higher values of illumination to meet the requirements of colour television.
The design brief required that the values of horizontal and vertical illumination should be as high as possible within the limitations of the windage area of lighting fittings on the existing lattice steel towers and the capacity of the existing feeder cables.
With these requirements in mind the new installation was designed on the basis of a one-for-one replacement of the existing 1 500W tungsten filament projectors (over-run by 10%) with 1 000W mercury iodide lamps in new projector fittings with 24in diameter reflectors. These fittings can be accommodated in the existing head frame construction.
The mercury iodide lamp provides a compact, high brightness source of good colour in a clear bulb. By the use of iodides of various metals in the arc tube, colour correction is achieved without the need for a coated outer bulb.
This lamp and fitting combination allows accurate and efficient optical control by the reflector, ensuring an acceptable degree of glare control. Higher wattage lamps with longer arc tubes in the same size of fitting would be relatively inefficient and would cause both discomfort and disability glare to the spectators. The use of substantially larger fittings to overcome this problem would introduce difficulties of head frame mounting with the additional disadvantage that one lamp failure on a high wattage installation has a more significant and localised effect on the pitch illumination than an equivalent random failure of a lower wattage lamp.
The installation provides an average horizontal illumination of 700 lux (through life). This represents an increase of four times compared with the original installation, with a 20% reduction in load.
The control gear to operate the lamps has been installed in cabinets specially designed by the contractor and mounted at the rear of the covered stands adjacent to the tower positions, with multi-core cables running from this position to the head frames.
Looking to the future, mercury iodide lamps are capable of satisfying the full requirements of colour television by providing values of illumination in the region of 1 000 lux, in a plane 15 deg from the vertical facing the camera position, allowing full use of long focus lenses, adding much to the spectacle of televised sport. These requirements can represent a tenfold increase in the existing value of horizontal illumination; where suitable mounting positions are available mercury iodide lamps can achieve these higher levels with less than a 50% increase in the load of most present-day installations.

The installation at Molineux Park was designed by France's Engineers Limited, Darlaston, Staffs, in collaboration with the Lighting Engineering Department of Thorn Lighting Limited.

metrication in the lighting industry

by Gordon V McNeill CEng MIEE FIllumES

part iii: the solution

The first two articles in this series outlined the basic plan for Britain's ten-year programme of metrication between 1965 and 1975 and pointed out the problems associated with the decision to adopt a first preference building module of 300mm (11.81in). This reduction of only about 3/16th of an inch in going from foot to 300mm modules enables many building materials or components to be reduced slightly in size without serious conversion problems, but this does not apply to modular lighting fittings for use with tubular fluorescent lamps. This concluding article therefore confines itself to practical solutions of the problem of designing metric modular lighting fittings which incorporate fluorescent tubes.

BSI Functional Group Panels

To resolve the practical problems affecting the choice of preferred metric basic spaces in building, the BSI set up a number of specialist committees with representatives from all sectors of the construction industry: representatives were selected on the basis of product application. These specialists were formed into six Functional Group Panels, each covering a section of building work as indicated in Table 1. The two panels of primary interest to the lighting industry are

FGP 1	Structure, e.g. foundations, columns, walls, floors and roof
FGP 2	External envelope, e.g. windows, doors, insulation and cladding
FGP 3	Internal subdivision, e.g. partitions, finishings and ceiling panels
FGP 4	Services and drainage, e.g. electrical, heating and lighting systems
FGP 5	Fixtures or equipment, e.g. kitchen and sanitary equipment
FGP 6	External works (provisional section for further study)

Table 1 BSI Functional Group Panels

FGP3 and FGP4 both of which included representatives from the ELIC lamp and ELFA fitting organisations (now amalgamated to form the Lighting Industry Federation).

In the case of FGP3, which deals with internal subdivision, the representative of the Metal Fixing Association for Ceiling Systems reported that metric suspended metal ceiling grids will be based on 600mm or 300mm modules and a slight preference was indicated for grids based on the 600mm module. This suggests that the first preference will be for 600mm grid width with lengths of 600, 1 200, 1 800 or 2 400mm. Where the 300mm grid width is used, it would be

This is the third and final article dealing with the British Government's programme for metrication, with special reference to the activities of the British Standards Institution on metric co-ordination and its probable effect on the lighting industry. Gordon V McNeill is Technical Training Manager at the Thorn Lighting training centre at Leicester.

possible to consider basic space lengths of 600, 900, 1 200, 1 500, 1 800 or 2 400mm, i.e. the metric equivalents of 2, 3, 4, 5, 6 and 8ft modules.

It should be noted that the BSI metrication committees still have the considerable problem of resolving metric tolerances and fits for practical work sizes of components which combine to fill a given basic space. The effect of boundary conventions for the trespass of walls or partitions into a basic space is also being investigated in detail. This article is therefore only a progress report on action taken to date.

Metric lighting problems

The British lighting industry has issued a statement on metrication which points out the special problem associated with the use of fluorescent tubes in the proposed metric modular spaces, and the data shown in Table 2 were included in the statement. This shows

Nominal fluorescent tube length	*8ft*	*6ft*	*5ft*	*4ft*	*3ft*	*2ft*
	mm	mm	mm	mm	mm	mm
Overall length from end of opposite pins (maximum)	2 389	1 780	1 514	1 214	909	604
Add: 3mm each end of lamp for minimum lampholder thickness	2 395	1 786	1 520	1 220	915	610
Add: 9mm minimum for removal of lampholder at one end of lamp	2 404	1 795	1 529	1 229	924	619
Add: Thickness of painted metal ends of fitting (3mm) and manufacturing tolerances on metal work (2mm)	2 409	1 800	1 534	1 234	929	624
Nearest 300mm basic space module	2 400	1 800	1 500	1 200	900	600

Table 2 Relation of practical lengths of recessed troffer fittings to lengths of basic space modules

how the length dimensions of practical recessed troffer type fittings compare with the proposed metric basic space modules.

With the exception of the 6ft bi-pin fluorescent tube, the overall dimensions of the fittings in Table 2 are in excess of the basic space module, although it would be possible to design a special 2 400mm system which could accommodate the 8ft tube length. For all other tube sizes the overall length of the tube itself is in excess of the basic space: this means that tubes can be used only if they are allowed to trespass into the adjoining basic space. Alternatively, the next shorter length of tube can be used, e.g. a 4ft tube in a 1 500mm basic space. The only other solution would be to create a completely new range of fluorescent tube sizes, about 40 or 50mm shorter than the existing 5, 4, 3 and 2ft tubes.

International standardisation

The British lighting industry statement pointed out that because the existing range of fluorescent tube lengths has been nationally and internationally agreed in BS.1853 and IEC.81 specifications, and because replacement Imperial tube lengths would be required for many years, the introduction of a new metric tube range of reduced lengths would involve the lighting industry in double-stocking for a period well beyond 1975. Since this would increase manufacturing costs and cause international conflict on standardisation, the proposal for a new metric tube range was found to be unacceptable.

It is unfortunate that the lighting industry is faced with this special metrication problem. Imperial fluorescent tube sizes are also the current international sizes which are used by all metric countries, so no hasty decision should be made to introduce new metric tube sizes without fully investigating all other solutions. The development of new light sources and interior lighting techniques must be taken into account when looking ahead to the next decade and trying to forecast the nature of future lighting practice. In the meantime, at least one practical solution can be offered to the designers of metric modular buildings.

Metric modular fluorescent lighting

Table 2 has shown that a practical recessed metric troffer fitting of 1 800mm modular length can be manufactured which will accommodate the existing 6ft bi-pin fluorescent tube. A check was therefore carried out as to the use of 6ft tubes in surface modular type fittings and Figure 1 shows how the existing 6ft tube of 1 780mm overall pin-to-pin length (maximum) fits into an 1 800mm basic space.

The lower section in Figure 1 shows how the tube can be removed from leaf spring rocker type lampholders without trespassing outside the basic space module. This means that if manufacturing tolerances can be controlled to within a few millimetres then it is possible to design both surface or recessed fittings of 1 800mm overall length. After further investigation it has been found possible to reduce the existing 6ft tube length by 2mm without affecting mechanical or electrical interchangeability in existing fittings. The British lighting industry has now agreed to adopt a reduced overall length of 1 778mm for the 6ft (or 1.8 metre) tube and this revision is being submitted for inclusion in BS.1853.

The proposals for general lighting in metric modular buildings can therefore be summarised as follows:

(a) For industrial buildings: use the existing 8ft 85W or 125W fluorescent tubes with a 3 metre metric space module.

(b) For commercial buildings: use the modified 6ft 85W fluorescent tube of 1 778mm overall length with a 1.8 metre module.

One further advantage in standardising on 8ft and 6ft fluorescent tubes is the fact that these long tubes are more efficient and economic to instal and operate compared with 5ft or 4ft fluorescent tubes. In the case of the 6ft tube, the introduction of Atlas amalgam-controlled 6ft tubes (*referred to elsewhere in this issue*) makes it ideal for totally enclosed commercial fittings normally used for office lighting. The gain of up to 20% in light output, combined with effective utilisation of the full 1 800mm length module, make it possible to obtain very economic performance from metric fittings designed around the 1 778mm fluorescent tube rated at 85W with 0.80 A loading.

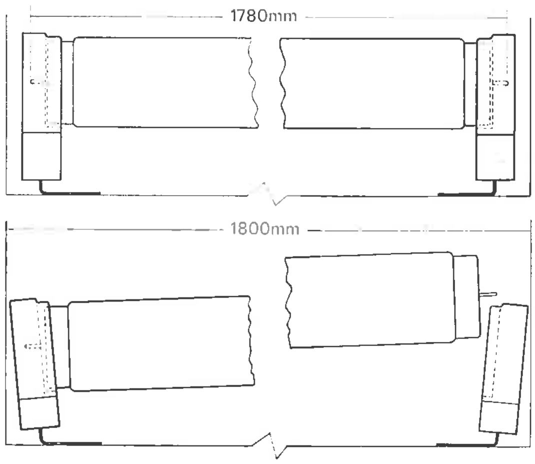
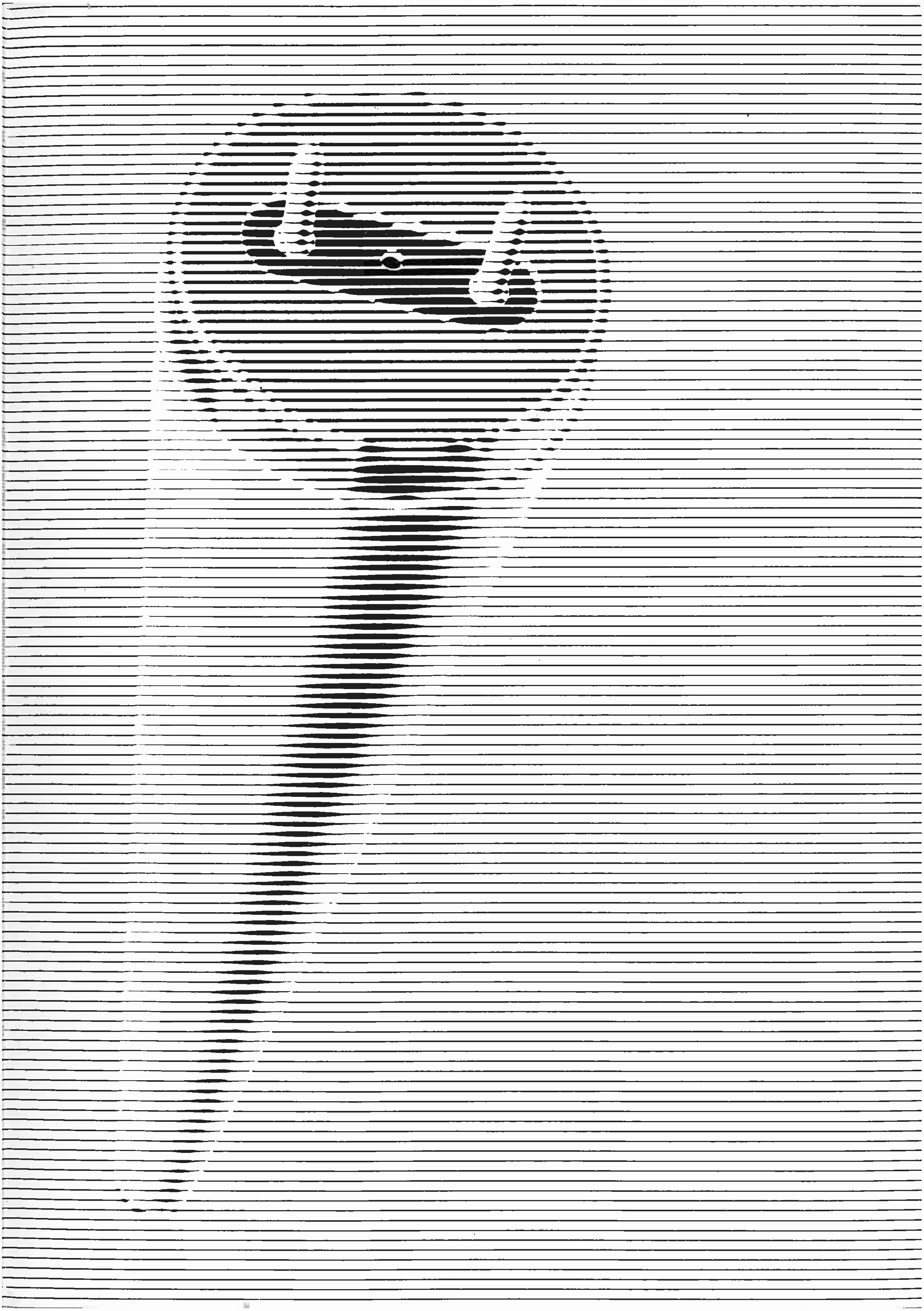


Figure 1 Existing 6ft tube in 1 800mm basic space using leaf spring lampholders.
Top Tube in normal working position.
Bottom Tube in process of being removed: shroud of lampholder slotted for pin removal.



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