Technical advice note on high frequency lighting

Produced by the Lighting Industry Federation, Electrical Contractors' Association, Electrical Contractors' Association of Scotland, with the Energy Saving Trust and published with the support of the Energy Efficiency Office of the Department of the Environment
The Energy Efficiency Office of the Department of the Environment promotes cost-effective energy efficiency technologies. High frequency ballasts for fluorescent lamps are such a technology, giving energy savings of 20 to 30%.

The EEO has therefore published this guidance note to help spread the use of high frequency ballasts. Further information on high frequency lighting can be obtained from:

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This document was produced by BRECSU on behalf of the Energy Efficiency Office.
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High frequency (HF) operation of fluorescent lamps is one of the most important developments in lighting. HF systems make possible energy savings of 20-30%, with a reduced cost of ownership. In addition, HF operation brings improvements in increased visual comfort (through the absence of flicker), in starting, in noise reduction and reduced stroboscopic effect and in general operating conditions.

The use of HF equipment means, however, a number of changes in practice for luminaire installers, and this 'Technical advice note' is intended to ease the transition.

Though ‘fixed’ output HF ballasts achieve significant improvements in energy costs and operating conditions, later generations of ballasts, which offer variable light output in response to a control signal, make possible even further economies.

Such ‘controllable’ HF ballasts have also brought about changes in lighting design techniques. Since the light output of the lamp is no longer fixed, the lighting pattern over an area, or from time to time, can readily be changed.

HF lighting is more than an advance in lighting equipment technology - it now opens up new possibilities in lighting engineering practice.

For both luminaire installers and manufacturers alike, these notes offer only general guidance, and the luminaire manufacturers data should always be consulted for specific application information.
2. DEFINITIONS AND EXPLANATORY NOTES

2.1 Ballast
A unit inserted between the supply and one or more tubular fluorescent lamps which serves mainly to limit the current of the lamp(s) to the required value. The unit may consist of one or more separate components. It may also include means for transforming the supply voltage and arrangements which help to provide starting voltage and preheat current, prevent cold starting, correct the power factor and/or suppress radio interference.

2.2 AC supplied electronic ballast
(HF ballast)
A mains supplied ac to ac inverter including stabilising elements for starting and operating one or more tubular fluorescent lamps, generally at high frequency.

Note: This is the internationally agreed definition. For these Advice Notes the term HF Ballast will be used as this is in general use.

2.3 High frequency controllable ballast (HFC ballast)
An HF ballast which responds to an external control signal and varies the power delivered to the lamp in order to control the light output of the lamp(s) and the energy consumption of an installation.

Note: An HFC ballast usually has special terminals for the connection of the external control signal. These ballasts are sometimes called Regulating or Variable Output HF ballasts.

2.4 Fixed output high frequency ballast
An HF ballast with no provision to respond to an external control signal to vary the power delivered to the lamp.

Note: Some ballasts may, however, have internal means to stabilise the power delivered to the lamp despite variations in the supply voltage.

2.5 Phase controlled high frequency ballast
A high frequency ballast which can be connected to a commercial quality phase controlled dimmer to vary the power delivered to the lamp.

Note: Such HF ballasts are typically used where fluorescent and incandescent sources are integrated within a dimmable system.

2.6 Luminous efficacy

- of a lamp:
The ratio of light output (Lumens) to lamp power (Watts) under specified ambient conditions.

- of a circuit:
The ratio of the light output from a lamp (Lumens) to circuit power (Watts) under specified ambient conditions.

2.7 Fluorescent lamps
There are three principal types of linear fluorescent lamp, and a variety of 'compact' types in several formats.

- Krypton filled lamps
These are normally available in a diameter of 26 mm in lengths below 2400 mm (the 100 W 2400 mm lamp is 38 mm diameter), and may be used with suitable appropriate HF ballasts.
- **Argon filled lamps**
  These are normally available in a diameter of 38 mm and are now regarded as second-choice lamps and should be used for replacement purposes only, especially for starterless circuits.

- **HF Argon filled lamps**
  These lamps are only available in a diameter of 26 mm and are designed for optimum operation on appropriate HF ballasts.

- **Compact lamps**
  These are of a folded tube construction and are available in various shapes including: 2, 4 and 6 limb; 'Square', and 'L' (longer) forms. Only 4 pin types are suitable for operation on HF ballasts. A more detailed description is available in the 'LIIF 1994 Lamp Guide'.

### 2.8 Supply voltage
The voltage applied to the complete circuit of lamp and ballast.

### 2.9 Circuit power/wattage
The total power taken from the supply, i.e. ballast losses plus lamp operating power.

**Note:** Published values of circuit power relate to a 'type' ballast, i.e. a ballast selected as most representative of production, operated under standard conditions.

### 2.10 Ballast Lumen Factor (BLF)

The ratio of the light output of a reference lamp operated with an objective production ballast, to the light output of the same lamp operated with a reference ballast, both measurements being carried out under the same reference conditions.

If the reference ballast is a conventional 50 Hz type, as is the case with lamps not designed exclusively for operation on HF, then, for a similar light output, the lamp power with the HF ballast will be lower than with the reference ballast. This contributes to lower operating temperatures, and the HF ballast manufacturer usually designs for a BLF slightly lower than unity to compensate for the more favourable thermal environment within a typical, well designed, luminaire.

### 2.11 Lamp life/service period
Since HF ballasts operate lamps at reduced power compared with conventional mains circuits, this results in a lower depreciation of lamp light output which may offer the possibility of extended service periods with HF operation (see also Section 6).

BS EN 60901 and BS EN 61199 (for compact fluorescent lamps), and BS EN 61195 (for fluorescent lamps) define the operating conditions and performance characteristics for such lamps, and reference should also be made to manufacturers' data.

### 2.12 Starting aid
An earthed metal plate, part of the luminaire itself for example, close to and extending the whole length of the lamp, to ensure reliable starting under a wide range of operating conditions. See also 8.4.
3. PRINCIPLES OF HF OPERATION

3.1 Improvement in circuit efficacy
By running fluorescent lamps above 10 kHz, an increase in lamp efficacy of around 10% can be expected when compared with 50 Hz operation. HF ballasts, however, need to operate above the audible range and, with increase in frequency, can also be made more compact. The choice of operating frequency is ultimately limited by ballast losses, and around 30-50 kHz represents a common compromise.

HF ballasts are designed to have lower losses than 'standard loss' conventional ballasts, contributing to an increase in circuit efficacy.

3.2 Exploiting the gains in efficacy
In application, the improved losses are reflected in a more favourable thermal environment within the luminaire, reducing lamp wall temperatures such that the lamp phosphors operate in a more efficient region.

Most ballast manufacturers choose to take advantage of this improved efficacy by offering the same light output as conventional circuits, but with reduced power consumption. Some controllable ballasts may, however, be designed to deliver more than the normal 50 Hz light output, to facilitate compensation for lamp lumen depreciation.
High frequency operation of fluorescent lamps can be used wherever ordinary fluorescent lighting is used e.g. offices, shops, factories, hotels, the home.

4.1 Application queries

**Q1** Can high frequency lighting be used at low temperatures?

**A1** The light output from fluorescent lamps is significantly reduced at low temperatures. HF ballasts will start lamps in sub-zero temperatures but at this ambient temperature the light output may be reduced to 30% of the 25°C level and, with controllable ballasts, the range over which the light output may be adjusted will decrease. Luminaire design must ensure that the lamp wall temperature approaches the optimum - if not, striations and reduced light output may result.

**Q2** Do HF ballasts create electromagnetic interference (EMC)?

**A2** All electrical equipment produces, or may be susceptible to, some degree of electromagnetic interference, but the European Directive on Electromagnetic Compatibility (EMC) requires that luminaires incorporating HF ballasts should not only be immune to particular levels of electromagnetic disturbance, but also comply with well defined limits of conducted and radiated emissions (see Appendix 1 for further information).

**Q3** Will HF ballasts interfere with 'clean' supplies to computer installations?

**A3** Well designed and installed HF ballasts complying with BS EN55015 regarding limits for radio interference voltages and radio interference fields (mains borne and radiated interference) and with BS EN60555-2 for supply current harmonics will not give rise to any greater problems than other well designed electrical equipment used in the vicinity of computers.
What effect will HF operation have on stroboscopic effects with rotating machinery?

The absence of flicker and very low modulation of the light output with HF ballasts means that there are no detectable stroboscopic effects which, on mains frequency circuits, may make rotating machinery appear to be stationary.

What are the differences between controllable and phase controlled HF ballasts and their applications?

Whereas controllable HF ballasts have integral means by which the light output may be varied in response to signals applied to their control terminals, phase controlled HF ballasts can be supplied from phase controlled dimmers to similarly vary the power to the lamp.

Controllable ballasts are typically used in energy management or lighting control schemes under system, photocell or occupancy control, whilst phase controlled ballasts are more often combined with dimmed incandescent sources to create particular aesthetic effects, and where the dimmer control signals are derived from manual potentiometers or push-button programmed faders (see Part 3 for more information).

Can HF ballasts be incorporated into emergency lighting schemes?

Most manufacturers of emergency lighting equipment can provide effective solutions to the embodiment of HF ballasts in emergency lighting schemes. Occasionally, however, where HF ballasts are used with self-contained emergency modules, there may be incompatible internal connections, protection systems or test requirements and so the user should always refer to the manufacturers for guidance. Where emergency modules are remote mounted, potential problems with lamp operation and EMC may be minimised by strictly observing the manufacturer’s recommendations on connecting lead lengths, typically a maximum of 1 metre.

Many HF ballasts can be operated on dc central battery systems which, provided the recommended voltage range is maintained, offers a possible alternative.

Systems employing central inverters or generators represent a further option, though where the ac supply is non-sinusoidal or has a relatively high source impedance, consultation with the equipment manufacturers is again advised. Such systems may also have relatively long start-up times, making it difficult to achieve the required light output within the specified time period after loss of the mains supply, though the problem is not confined to HF ballast installations.
Can HF ballasts be used in conjunction with energy limiters?

HF ballasts are designed to operate fluorescent lamps at optimum power for maximum efficacy on normal mains supplies. Energy limiters therefore serve no purpose in lighting systems using HF ballasts. Indeed such devices interposed between the supply and the HF ballast may interfere with the ballast circuitry and will invalidate the ballast manufacturer's guarantee. It is not unusual for HF ballasts to incorporate stabilising circuits to hold the lamp power virtually constant during mains supply variations, thus rendering energy limiters ineffective and therefore redundant (see LIF Technical Statement No. 3 - Energy limiters and Tubular fluorescent lamps, Issue 5, November 1992).

Are controllable and phase controlled HF ballasts suitable for use in lecture theatres and conference facilities?

Many ballasts are intended for energy saving where a reduction in light output down to around 20% is acceptable. Others are designed specifically for controlling ambient light levels down to approximately 1% and are more appropriate for such applications. Lamps running on HF ballasts can, however, emit infrared at a similar frequency to that of some IR remote controllers for slide projectors and video equipment etc., and care should be taken to position or shield receivers accordingly, though modern systems employing high carrier frequencies and digital encoding should not cause problems.

Note: Some controllable HF ballasts remain at their minimum level even when the applied control signal is reduced to zero. In these circumstances, a means of isolating the power to the ballasts should be provided at the control position if the fluorescent lighting is to be completely turned off during, for example, presentations or lectures.

Is there any detectable flicker associated with HF operation?

Flicker is not a problem with well designed HF ballasts.

Can HF ballasts be used with PIR (Passive Infra-Red) movement detectors?

Depending on the application PIR detectors can switch lamps regularly and, since lamp life is related to switching frequency and ballast type, the manufacturers data should be consulted to select the most appropriate ballast for the application.
5. LAMP COMPATIBILITY (LINEAR T8/T12 AND COMPACT)

All HF ballasts are suitable for Krypton lamps. However, for T8 and T12 Argon lamps and compact fluorescent lamps, the ballast manufacturer should be consulted.

6. ADVANTAGES FOR THE USER/SPECIFIER

In addition to being recognised as one way of achieving the requirements of 'Approved Document L' of the Building Regulations relating to the conservation of fuel and power, the use of HF ballasts offers considerable other advantages to the user and specifier, viz:

**First time starting**

Unlike conventional switch-start circuits, lamps start at the first attempt, typically within 1-2 seconds.

**Reduced noise**

Conventional chokes use laminated sheet steel cores which tend to set up a vibrating noise under the influence of a constantly reversing magnetic field. HF ballasts operate at frequencies well above the audible range, use components which do not buzz or hum, and, as a result, operation is very much quieter than with conventional, mains frequency ballasts.

**Flicker free lighting**

Lamps operated from conventional ballasts exhibit a small amount of flicker. This is due to mains frequency variations of the light output in the area of the lamp cathodes, capable of being perceived by some individuals, and modulation of the light output at twice that frequency along the length of the lamp which, in a very small percentage of the population, may produce some discomfort.

HF ballasts eliminate entirely the 50 Hz variations at the lamp cathodes and, since they are capable of delivering power to the lamp throughout the period of the mains cycle, they also reduce the 100 Hz modulation of the light output to imperceptible levels.

**Detection of failed lamps**

Many HF ballasts will shut down upon detecting open circuit lamp cathodes during lamp starting, and will also switch off if an arc current fails to be established after a prescribed number of starting attempts, as may be the case with, for example, a leaking lamp.

The annoying flashing associated with the repeated starting attempts of conventional switch-start circuits in similar circumstances is therefore eliminated.

**Automatic restart after lamp change**

Where failed lamps have caused the HF ballast cut-off function to operate, it is important to remember that the circuit is essentially still LIVE, and could generate high voltages if lamp replacement is attempted in this condition. Therefore, for reasons of safety, the mains supply must be switched OFF before removing and replacing any lamps.

In multi-lamp circuits, the failure of a single lamp may cause some HF ballasts to shut down all lamps, and in such circumstances the failed lamp may not be easily identified. However, apart from premature failures, it is likely that the lamps would be nearing the end of their useful life and replacement of all lamps is therefore recommended.

The HF ballast does not require any manual resetting, and will restart the lamps automatically upon restoration of the supply.

**Lower lamp lumen depreciation**

The reduced power in the arc of lamps operated on HF ballasts results in slower
deterioration of the light output, and may be used to advantage when considering planned lamp replacement (see the 1994 LIF Lamp Guide), or in design to a given 'Maintained Illuminance' in accordance with the 1994 CIBSE Code for Interior Lighting.

Lightweight luminaires
A 1500 mm fluorescent lamp luminaire with an HF ballast weighs less than a similar luminaire incorporating conventional 50 Hz control gear. This weight reduction results in easier handling of luminaires during transport and installation and less strain on supporting systems or surfaces.

High power factor circuits
Well designed HF ballasts have a power factor of almost unity.

Low mains pollution
HF ballasts meeting European standards for supply current harmonics and conducted radio interference have the low levels of mains pollution expected of any other carefully designed electronic equipment.

Stabilised light output
Many fixed output HF ballasts are able to maintain the power delivered to the lamp over a wide range of supply voltage variations. Controllable HF ballasts offer the further advantages of flexibility and increased economy of operation and installation (compared with conventional controlled systems), and enhanced levels of environmental comfort.

Maintained illuminance
Controllable HF ballasts, when used with appropriate light sensors, are capable of both maintaining illuminance over a range of ambient lighting conditions and compensating for the effects of lamp ageing.

7. QUALITY AND RELIABILITY

7.1 Reliability
Reputable ballast manufacturers use only quality assured components, selected and tested for the appropriate performance margins in application, in circuits designed and manufactured under ISO 9000 (BS EN29000) control, and 'environmentally stress screened' before dispatch. The user can therefore expect the highest possible standards of performance and reliability.

7.2 Compliance with standards
To ensure the HF ballast selected is safe and complies with the relevant requirements of the Low voltage directive and Electromagnetic compatibility directive it should be capable of meeting the following standards:

<table>
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<th>BS EN 60928</th>
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<td>AC supplied electronic ballasts for tubular fluorescent lamps - general and safety requirements.</td>
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<th>BS EN 60929</th>
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<td>AC supplied electronic ballasts for tubular fluorescent lamps - performance requirements.</td>
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Guidance for Users, Specifiers and Contractors

**BS EN 55015**
Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment.

**BS EN XXXX**
EMC Product family standard - 'immunity requirements for equipment for general lighting purposes'.

**Note:** Though BS EN60555-2 relating to supply current harmonics does not currently include lighting products, 2nd editions will do so, and will be published as IEC 1000-3-2 and BS EN61000-3-2.

7.3 Compatibility with wider voltage ranges
It is important for correct operation of the ballast in the UK to ensure that the ballast will operate satisfactorily over the present and anticipated UK voltage range. These ranges are currently changing and are:

- Up until 31st December 1994: 240 V±6% (i.e. 264 V - 225 V)
- From 1st January 1995: 230 V±10%±6% (i.e. 253 V - 216 V)
- From 1st January 2003: 230 V±10% (i.e. 253 V - 207 V)

As electrical equipment currently needs only to declare the rated voltage, it is important to determine the voltage range from the manufacturer.

8. INSTALLATION AND SERVICE GUIDANCE

The following matters are of particular relevance to electrical contractors when using HF ballasts.

8.1 Installation insulation resistance testing
In common with other electronic products, HF ballasts must not be subjected to the insulation resistance tests on installation wiring described in BS 7671 (Requirements for electrical installations IEE wiring regulations 16th edition).

Regulation 713-04-02 states that 'electronic devices' shall be isolated so that they are not damaged by the test voltage, though most ballasts can now accept up to 500 V dc, applied for no longer than 2 seconds, between line and neutral joined together and earth, but not between line and neutral.

However, the leakage paths inherent in HF ballasts may cause lighting circuits to apparently fail the insulation tests, and prior disconnection of luminaires is therefore recommended.

8.2 Residual Current Devices (RCDs)
The RFI filters incorporated in HF ballasts include capacitors connected between line and earth, and neutral and earth, allowing a small amount of 50 Hz current to flow through the earth conductor which is interpreted as earth leakage current by the 'Residual Current Device'.

As a general rule, the leakage current may be assumed to be not more than 1 mA per twin luminaire.
8.3 Miniature Circuit Breakers (MCBs)
At switch on, HF ballasts draw a surge of current from the supply. MCBs cannot, therefore, be selected on the basis of steady state current demands. Several MCB surge profiles are available, and, for HF lighting circuits, the Type 3 characteristics defined in BS 3871, or the later Type C characteristics in BS EN60898, are recommended as a minimum.

The number of HF ballasts which may be operated in a circuit protected by a given MCB may vary with ballast design and therefore the installer is advised to refer to the manufacturer's information for guidance.

8.4 Starting aid
HF ballasts may require a lamp starting aid for satisfactory operation, which must be used if specified by the manufacturer. This will normally be in the form of an earthed metal plate electrically connected to the ballast (e.g. part of a luminaire), at a maximum distance of 15 mm from the lamp wall, and extending along the whole of its length.

8.5 Master/slave operation
Though generally not considered to be best practice, nor recommended for all ballasts, where two single lamp luminaires are to be installed with a twin lamp HF ballast in one luminaire only, the following installation practice is advised.

a) The leads from the HF ballast to the furthest end of the 'slave' lamp should not exceed the limits stated by the ballast manufacturer.

b) The leads between luminaires must be screened to avoid radio interference problems.

c) Both luminaires must be earthed by means of an interconnecting earth lead for good interference suppression.

8.6 Internal cables
To minimise radio-frequency interference, it is important that supply cables within luminaires do not run adjacent to leads connected to the ballast output terminals, and where crossing is necessary, this should be arranged at right-angles.

8.7 External supply and control cables
Where low voltage (supply) cables run adjacent to extra low voltage (control) cables, regulation 528-01-02 of BS 7671 (Requirements for electrical installations IEE wiring regulations 16th edition) specifies that the level of insulation should be the same for both, i.e. at the higher level.

8.8 The use of MICC
Due to their high frequency losses, MICC or similar construction cables cannot be used for HF ballast lamp connections in master/slave configurations for example, though they are quite suitable for luminaire mains supply purposes.

8.9 Retrofit precautions
The mixing of magnetic and HF ballasts on the same circuit is not recommended under some circumstances and without prior consultation with the manufacturers.

For example, where a conventional installation employing lead/leg luminaires is to be re-equipped with HF ballasts, progressive retrofitting should be avoided due to the potentially damaging switch-off transients generated by this type of control gear.
Parallel capacitor power factor corrected circuits suppress such disturbances and therefore present no problems, though, when installing HF ballasts, the PFC capacitor and other components should always be isolated or removed from the luminaire along with the magnetic ballast.

8.10 Temporary supplies
Temporary supplies may have connected to them items such as, for example, lifts and welding equipment, which could produce electrical disturbances. The connection of HF ballasts to such supplies is therefore not recommended, and the installer is advised to check the supply where there is any doubt regarding its nature.
Though many ‘fixed output’ HF ballasts are capable of varying the power to the lamp, they do so automatically in response to supply voltage fluctuations. However, some types of HF ballast may be used to vary the light output of the lamp(s) by means of a variety of external controls.

9. HF BALLASTS FOR LIGHTING CONTROL

9.1 Controllable HF ballasts

Controllable HF ballasts are distinguished from fixed output types by their ability to accept external control signals as a means of varying the light output of the lamp(s). Separate terminals are normally provided for the control input, which may be analogue in the range 1-10 v. or digital.

9.2 Phase controlled HF ballasts

Phase controlled HF ballasts may be connected directly to a remote dimmer which varies the supply voltage to the ballast, and hence the power to the lamp(s). Unlike controllable ballasts, phase controlled ballasts have no separate control input, the control signals being applied to the phase controlled dimmer interposed between the ballast and its supply.

10. PERIPHERAL EQUIPMENT AND CONTROL SIGNAL TRANSMISSION

Control signals may be derived from a variety of sources including, for example, simple manual potentiometers, push button panels, programmed lighting systems, light level and occupancy sensors, or even computerised ‘building management systems’.

The methods of conveying these control signals to the dimmer or ballast control inputs are equally diverse and may involve the use of, amongst others, direct ELV connection (see 8.7 – External supply and control cables), telephone or fibre optic links, infra-red and mainsborne communications, or various bus systems.

Whatever the choice of sensor and transmission system however, it must either be directly compatible with, or have available a suitable interface to the control input and protocol, and therefore the usual precaution of seeking the manufacturers’ guidance is advised.

A full discussion of control options is beyond the scope of this advice note. However, a guidance document, ‘Lighting Control’, is available from the Lighting Industry Federation which describes, in more detail, control techniques for a wide range of applications.
11. ADVANTAGES OF HF BALLASTS IN LIGHTING CONTROL

Controllable and phase controlled HF ballasts enjoy all the advantages of fixed output types highlighted in Section 6 but, in addition, can offer significant improvements in aesthetic effect, environmental comfort, energy management and in installation and lighting practice.

11.1 Improvements in installation practice

With controllable ballasts, 'dimming' is an integral function and no separate regulator is required.

Phase controlled ballasts may be retrofitted into existing systems incorporating phase controlled dimmers without requiring any additional control wiring or means for isolating the ballast from the supply to turn off the lamps (see Section 4.1 - Application queries A9, note).

If a central controller is employed, the switching pattern can easily be changed to suit different room arrangements, eliminating the need for individual sub-circuit switches.

'Wireless' switches can obviate the need for conventional hard-wired switch drops.

Some controllable HF ballasts can be powered directly from a central battery without requiring inverters, the light level in emergency situations being either preset or varied appropriately during the period of evacuation.

11.2 Improvements in lighting practice

Illuminance can easily be varied in accordance with a programmed time regime, or with level of occupancy.

Similarly, it is easy to accommodate a change of use by setting different light levels according to whether, for example, an area is employed as storage or as office space.

Illuminance can be maintained in response to natural lighting conditions, or to the effects of lamp ageing.

The facility for local override means that individual user preferences, either in respect of light levels or working hours, can be accommodated within a central control system designed to reduce energy consumption in unoccupied areas or at certain times.

Where lighting control is employed for purely aesthetic purposes (lobbies, restaurants, aria) or functional purposes (conference facilities, board rooms, lecture theatres), phase controlled ballasts allow fluorescent lamps to be integrated with other types of dimmed load.