Safety Regulation Group

CAA PAPER 2008/01

Specification for an Offshore Helideck Status Light System

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Specification for an Offshore Helideck Status Light System

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Foreword

A specification for an offshore helideck status light system was produced and published in CAA Paper 2003/06. Although the specification itself remains satisfactory, a small ambiguity in the associated flashing light test procedure (contained in Appendix B), together with the possibility for misinterpretation of the corresponding material contained in the ICAO Aerodrome Design Manual Part 4, Visual Aids (Doc 9157 AN/901), material closely associated with the specifications contained in ICAO Annex 14 Volume I, has led to unintended interpretation and status light systems that fall significantly below the required performance.

Consequently, the CAA commissioned an independent review of the measurement and calculation of the effective intensity of flashing lights at the UK National Physical Laboratory (NPL). The review recommended some minor changes to the flashing light test procedure of CAA Paper 2003/06, which have been incorporated in the updated specification presented in this paper. An unabridged version of the NPL review is included at Appendix C.

The specification contained in this paper supersedes that detailed in CAA Paper 2003/06, and will be referenced in CAP 437 (Offshore Helicopter Landing Areas: Guidance on Standards).

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Specification for an Offshore Helideck Status Light System

1 Introduction

This report provides a recommended technical specification for an offshore helideck status signalling system in support of the CAA's best practice guidance material published in CAP 437 “Offshore Helicopter Landing Areas – Guidance on Standards” (Reference [1]). The operational requirement for the system is described along with the development of the technical specification. A test procedure for the measurement of the performance of flashing lights intended for use as helideck status lights is also presented.

2 Background

The CAA's attention was initially drawn to the issue of helideck status signalling systems as a result of concerns within the industry over 'wrong-rig' landings and their associated safety hazards. A study of offshore platform identification signs, reported in CAA Paper 92006 (Reference [2]), established that there was little prospect of resolving the problem through improvements to the signage and recommended the specification of a new visual aid, the helideck status signalling system.

Although it was recognised that such a system could not prevent a helicopter landing on the wrong platform, it could help prevent it landing on a platform which is in an unsafe condition. A follow-up study was therefore commissioned with the objective of developing a specification for a status signalling system that was capable of indicating the three discrete helideck conditions of:

- the deck is safe and fit to land on;
- the deck is safe but not manned;
- the deck is unsafe to land on.

This study, performed by DERA Bedford in 1993 and reported in CAA Paper 93020 (Reference [3]), identified the practical difficulties of providing such a system. The solution would likely be complex and expensive and the study therefore recommended implementing a system for indicating the 'helideck unsafe' condition only.

As a result of this study a modified objective for the project was accepted. This was 'to develop and validate a specification for a light signalling system for offshore platforms capable of warning pilots of approaching helicopters if the helideck is in an unsafe condition'. Examples of an unsafe helideck were considered to be: the presence of a gas leak; moving machinery (e.g. a crane) in the area of the helideck; explosives in use on the platform; platform personnel working on or near the helideck.

DERA, Bedford was tasked with producing the photometric specification for the light system, and validating it by implementing it using available 'off the shelf' lighting equipment and conducting dedicated flight trials. The trials undertaken in support of the project were performed over the period December 1994 to February 1997, and the final report containing the specification was published as CAA Paper 98003 (Reference [4]).

Further developments in the industry and additional knowledge subsequently acquired, however, led to the identification of a number of gaps in the original specification and the need to improve the material. An update was consequently produced by the CAA's Research Management Department with the assistance of QinetiQ Bedford, and was published in CAA Paper 2003/06.

The CAA became aware, however, of status light systems being installed with a lower performance standard than had been intended. Investigation revealed that a small ambiguity in the flashing light test procedure and an incorrect, but understandable, misinterpretation of the corresponding material in the ICAO Aerodrome Design Manual Part 4 Visual Aids (Doc 9157 AN/901), material closely associated with the specifications contained in ICAO Annex 14 Volume I, had led a manufacturer to believe that the effective intensity of flashing lights with flash durations of 200ms or greater could be taken as the peak or 'steady burning' intensity. In order to be certain, the CAA commissioned an independent review of the measurement and calculation of the effective intensity of flashing lights at the UK National Physical Laboratory (NPL). The review broadly supported the existing specification contained in CAA Paper 2003/06, but recommended some minor changes to the flashing light test procedure. These changes have been incorporated in the updated specification presented in this Paper.

The majority of this Paper is therefore identical to CAA Paper 2003/06. The main changes are to the test procedure contained in Appendix B. In addition, an unabridged version of the NPL review is included in a new Appendix C.

3 Operational Requirement

The overall top level operational requirement for the system is to provide a light signal that the pilot will recognise as a warning whilst the helicopter is on the deck, and at any range within at least 900m from the installation at all azimuths in meteorological visibilities down to 1400m (day and night).

The minimum range of 900m (0.5NM) derives from the trials of helideck lighting systems performed at Norwich Airport during 2003 and 2004, where it was established as the range at which the pilot will be focussing more on the helideck than the platform as a whole, and from where an approach could safely be aborted if necessary. The present minimum decision range for helicopter approaches to offshore platforms is 1400m, and the minimum meteorological visibility is also 1400m.

It is recognised, however, that ongoing developments in the use of satellite navigation systems (e.g. Global Positioning System) for conducting offshore approaches may lead to a reduction in the minimum decision range in the future. Due to the constraints imposed by the obstacle environment, a minimum decision range of less than 900m (0.5NM) is not envisaged in the foreseeable future. The specification will therefore also address a second, future operational requirement relating to a minimum range of 900m in meteorological visibilities down to 900m.

4 Derivation of System Specification

4.1 Intensity

4.1.1 Requirement

The intensity of the system is determined by the range at which the signal needs to be seen, the prevailing meteorological visibility and the ambient lighting. With reference to Appendix A, it can readily be seen that the most demanding viewing condition is the bright day case. Although the probability of encountering the limiting meteorological visibility in such conditions is relatively low, the trials conducted during the earlier stages of this research project have demonstrated that the effectiveness of a light signalling system can be seriously impeded at night by the extraneous light existing at platforms that have a high level of cultural lighting. For a warning light to be effective at such platforms at night, it would need to be significantly brighter than the corresponding intensity required for 'typical night' viewing conditions, and probably similar to that required for bright day conditions. This implies that an intensity of 1758Cd is required to meet the stated operational requirement of a range of 900m in a meteorological visibility of 1400m (see Section 2 of Appendix A).

The overriding consideration in establishing the performance specification is the effectiveness of the system, i.e. the ease with which the pilot would be able to notice the signal. Given the meteorological visibility, the eye illumination threshold and the required viewing range, Allard's law provides the intensity of a steady light that would be 'detectable'. As detailed in Section 1 of Appendix A, these intensities should be increased by half an order (factored by 3.16) to give a figure that is considered to be 'conspicuous' (i.e. attention getting). This increases the intensity required from 1758Cd to 5555Cd.

It should also be noted that a system comprising two or more lights synchronised to flash alternately will confer greater conspicuity in a given set of viewing conditions as a result of the apparent 'movement' of the light source, and that the probability of detecting a light signal is also dependent on the viewing time.

4.1.2 Dimming

It can be seen from Appendix A that there is a large difference in intensity required for the full range of possible viewing conditions. It therefore follows that a system with sufficient intensity to meet the operational requirement in the worst-case conditions (i.e. at minimum meteorological visibility and on a bright sunny day or at night on a platform with a very high level of cultural lighting), may represent a significant source of glare in more benign viewing conditions.

This is not considered to be a significant issue while the helicopter is approaching the platform since the required pilot reaction is to abandon the approach, and performing the correct manoeuvre (climbing turn away from the platform) will result in the removal of any glare. The same is not true, however, in the event that the system is activated when the helicopter is landed on the helideck. At the very close viewing range in those circumstances the resulting glare would likely be severe and highly undesirable in such an emergency situation.

It is therefore recommended that some form of intensity control be provided. Where the system is installed on a manned platform this could take the form of a manually operated switch for the use of the Helicopter Landing Officer (HLO). The HLO would simply switch the system to dim once the helicopter had landed, and return the system to normal once the aircraft had departed. A means of automatically returning the system to normal after an appropriate time period (e.g. 30 minutes) should be provided to address the possibility that the system is inadvertently left dimmed. On NUIs, some form of automatic dimming would be required such as a proximity sensor to detect the presence of the helicopter on the deck.

From Reference [5], the intensity of any light visible to the pilot while landed on the helideck must not exceed 60Cd. The minimum intensity of the dimmed light should be 16cd.

4.1.3 Measurement of Flashing Light Intensity

Another very important factor associated with intensity is the method by which it is measured. The visual range characteristics of flashing lights is related to their effective intensity and, since the effective intensity measured is sensitive to the detail of the test procedure employed, it is important to establish a standard measure both for consistency and to ensure the suitability of any particular light for the application. A standard test procedure for flashing lights intended for use as helideck status lights is given in Appendix B.

The test procedure is a revised version of that contained in CAA Paper 2003/06 which, in turn, was based primarily on the Federal Aviation Administration's Advisory Circular 20-74 (FAA AC 20-74). The revisions to the earlier test procedure have resulted from an independent review of the measurement and calculation of the effective intensity of flashing lights performed by the UK National Physical Laboratory (NPL). A key part of this review involved checking the test procedure for consistency with the International Commission on Illumination (CIE) standards. At the time of the review, CIE had established Technical Committee 2-49 to prepare recommendations for photometric measurements of flashing lights, including the determination of effective intensity. Although CIE TC2-49 had not yet completed its work, broad consensus within CIE TC2-49 had been reached on the major issues relevant to the measurement of effective intensity and no significant changes are expected. The test procedure contained in Appendix B is therefore expected to be fully in accord with the CIE standards when they are published. An unabridged copy of the NPL review is given in Appendix C.

4.2 Beam Spread

4.2.1 Vertical Beam Spread

The vertical beam spread requirements for the status signalling system are determined by the vertical approach path of the helicopter, which has been established from data collected during normal in-service operations using the Helicopter Operations Monitoring Programme (HOMP). Vertical approach path data for 271 night approaches to 50 different offshore platforms was collected in connection with the production of a photometric specification for helideck perimeter lights, and is presented in Figure 1. The approach path data is converted to the corresponding angle of elevation from the helideck (and hence any light mounted on the helideck) as a function of range in Figure 2. As can be seen, the upper and lower limits of the vertical beam spread increase as the range from the helideck reduces. At a range of 900m the upper limit is 8.7° and the lower limit is 1.4°, and at 700m the upper limit is 9.6° and the lower limit is 2°.

A rational operational requirement associated with angles of elevation above the upper limit shown, is that the signal be available to the pilot as the helicopter flies overhead the platform during the downwind leg of the standard low visibility airborne radar approach procedure. A reasonable reference point is considered to be a position immediately above the platform where the angle of elevation is 90°, and the range is the procedural height above the sea of 1500ft (ignoring the height of the helideck which may be anything between 50ft and in excess of 200ft). As can be seen from Section 3 of Appendix A, this requirement leads to an associated intensity of 176Cd if the light is to be 'detectable', and 556Cd if the light is to be 'conspicuous'.

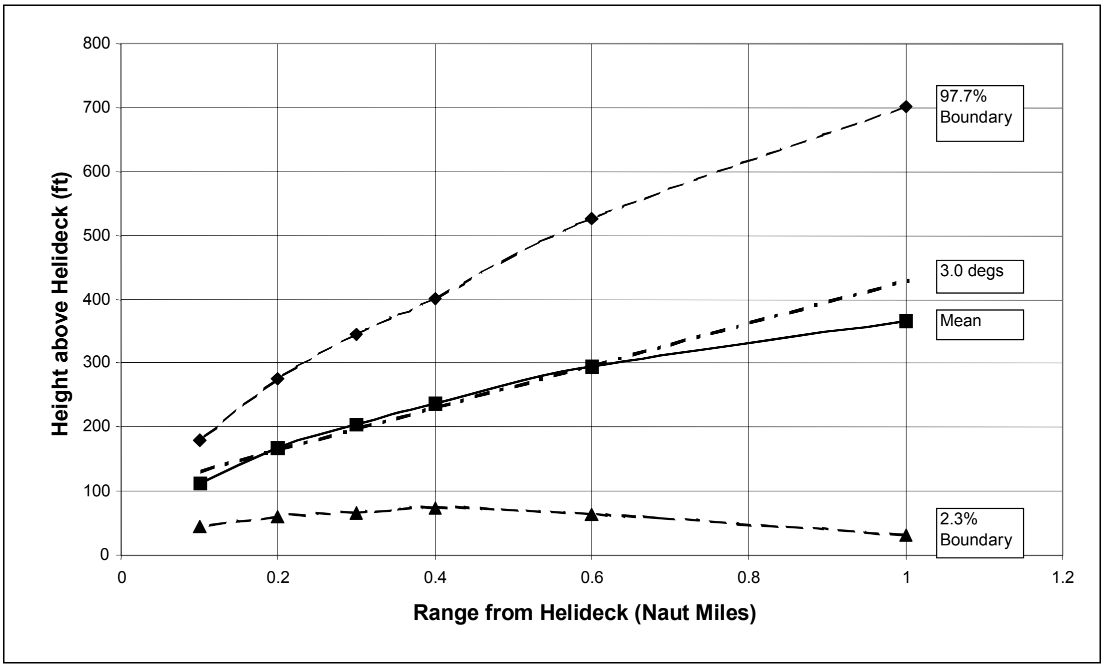


Figure 1 In-Service Data on Vertical Approach Profiles

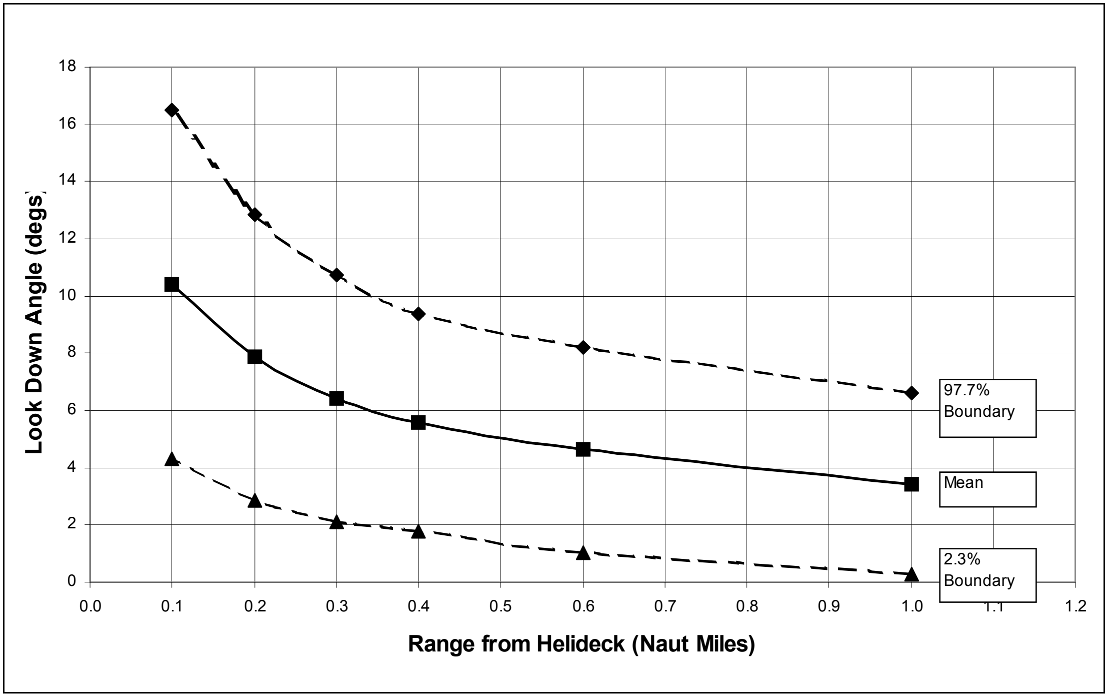


Figure 2 In-Service Data on Angle of Elevation of the Helicopter from the Helideck on Approach

4.2.2 Horizontal Beam Spread

Since a helicopter may, in principal, approach an offshore platform from any direction, the horizontal beam spread requirement for the status signalling system is 360°. Since the heading of a helicopter landed on a helideck is normally unrestricted, a sufficient number of light units must be provided to ensure that the pilot can see at least one light while on the helideck, regardless of the helicopter's heading.

4.3 Colour

A key factor in the recognition of a signal as a warning signal is the use of the colour red. This is encompassed in Table 4 in Section 2 of the UK Air Navigation Order where the interpretation of a red flashing light for aircraft in flight is defined as "do not land; aerodrome not available for landing", and "move clear of landing area" for an aircraft on the aerodrome. Red also has the benefit of being easily detected in the offshore environment due to the colour contrast it provides against the sea, sky or platform superstructure background. It is therefore very desirable to implement a practicable helideck status light system in red.

NOTE: In the event of the status light system activating while the helicopter is on the helideck, the action to be taken by the pilot will depend on instructions received from the HLO/radio operator on the platform. This will not necessarily result in the helicopter vacating the landing area.

The colour coordinates of the light should comply with the international standards for aeronautical ground lights, i.e. ICAO Annex 14 Volume 1 Appendix 1 Section 2.1.1 a). This defines the following CIE equations:

Purple boundary	$y = 0.980 - x$
Yellow boundary	$y = 0.335$

Although it is understood that other platform warning systems also utilise red flashing lights (e.g. sulphur dioxide release), they are located away from the helideck and comprise relatively low intensity lights. It is considered unlikely that they would be mistaken for helideck status lights, and such an eventuality would result in the helicopter aborting its approach, i.e. a safe situation. Conversely, due to their size and location, it is considered unlikely that the helideck status lights will be mistaken for any other platform warning systems.

4.4 Flash Rate, Flash Sequencing and Flash Duration of Light Units

The recommended flash rate of the status light system is 120 flashes per minute ±10%. This was the flash rate of the high intensity rotating beacon which was deemed appropriate by a number of pilots during the earlier in-service and dedicated flight trials reported in Reference [4]. In the event that all other system performance requirements cannot be achieved at this flash rate using a single light unit, a system can be formed using two or more lights each flashing at a slower rate. In this eventuality, the flashes from each of the light units should be synchronised to ensure that there is an equal time gap between each flash produced by the system as a whole.

A lower flash frequency of not less than 60 flashes per minute is considered acceptable for the purposes of designing the system to continue to function following any single system failure. It is stressed that this concession is to be applied on a temporary basis only, and it is expected that rectification to restore the full flash rate capability be carried out at the earliest possible opportunity. The lower flash rate of 60 flashes per minute is considered adequate while the helicopter is landed on the helideck, i.e. in the event that there are landing headings for which only one light is visible to the pilot.

The duration of the flash should be less than or equal to the duration of the off period, i.e. the duty cycle should be no greater than 0.5 or 50%. Hence, for a flash rate of 120 flashes per minute, the flash duration should be no greater than 250ms.

4.5 Activation

4.5.1 Triggering

Where practical and appropriate, the helideck status signalling system should be integrated with platform safety systems such that in the event of a process upset, e.g. a gas leak, the system is activated automatically. In addition, where installed on manned platforms, facilities must be provided for the HLO to manually switch the system on and to override the automatic activation of the system.

4.5.2 Start Up Time

It is also a requirement that the start up time for the light unit(s) when activated be effectively instantaneous. This is to ensure that there is no delay in indicating to the pilot that the helideck is in an unsafe condition, which is particularly important in the event of a warning being triggered when the helicopter is on the final stages of its approach to the platform. At a typical approach speed of 70kt, a helicopter will travel approximately 100m in 3 seconds. The maximum time to achieve the full specified intensity should not exceed 3 seconds from start-up.

4.5.3 Resetting

Consideration must be given as to how the system is to be reset once activated. On manned platforms, this might best be accomplished through the provision of a manual reset switch for use by the HLO. On normally unattended installations (NUIs), remote operation of any manual reset function would be necessary. Where this is not possible, then a practical solution might be for the system to be designed to automatically reset itself after an appropriate period of time (e.g. 30 minutes), provided that the system would re-activate if the hazardous condition still existed after reset. It is not considered acceptable to require a helicopter pilot to ignore the indication of a hazard and land in order for a manual reset to be performed.

4.6 Size of Unit

The light units used should be as small as possible in order to maximise the choice of location, and must comply with the height limitation (less than 25cm) of objects around the helideck. Where the light unit(s) used exceeds this limitation, consideration might be given to repackaging the unit to separate the lamp from the electronics unit, mounting the latter away from the critical height area of the helideck. Otherwise, it may be possible to position unit(s) on access/monitor platform(s) within the 210° obstacle free sector (OFS) (providing that units do not exceed the height restriction for the OFS and are visible from all directions of approach), or to mount the light unit(s) within the 150° limited obstacle sector (LOS).

4.7 Integrity

As a safety system, it is important that the helideck status signalling system operate when required to do so. This means that due account must be taken of the reliability of the individual components that make up the system and the system as a whole (including the electrical power supply), and that appropriate levels of redundancy are built into the system.

An alternative to redundancy would be monitoring which, necessarily, would have to be automatic in the case of systems installed on NUIs, but on manned platforms might be achieved through regular testing and inspection.

In addition, the system and its constituent components must meet all safety regulations relevant to the intended installation, e.g. explosion proofing (by a notified body in accordance with the ATEX directive).

4.8 Number and Location of Light Units

4.8.1 Number of Light Units

The requirement that at least one light be visible to the pilot when the helicopter is on the helideck, regardless of its orientation relative to the deck, effectively dictates that more than one light is required. However, given the very short range associated with this requirement, it could likely be met using supplementary 'repeater' lights of significantly lower intensity (a minimum intensity of 16Cd and a maximum intensity of 60Cd is recommended for lights deployed for this purpose) in addition to the 'main' signalling light(s).

In addition, the topsides layout of the platform (specifically the presence of superstructure above the level of the helideck which can obscure the pilots' view of lights located on the helideck), and the requirement that the signal be visible from any approach direction, may dictate the provision of more than one 'main' signalling light.

It is also a requirement that a single system failure should not render the whole system inoperative without warning. This implies a minimum of two 'main' signalling lights meeting the full photometric specification (except for flash rate if more than one unit is employed in order to meet the minimum flash rate requirement), unless a single light is equipped with a monitoring system capable of alerting platform personnel in the event of a failure (see Section 4.7).

Finally, the ability of a single unit of the type of light to be used to meet the photometric specification in the required colour and at the required flash rate may also dictate the use of more than one 'main' signalling light (see Section 4.4).

4.8.2 Location of Light Units

For maximum effectiveness and in order to avoid any potential confusion with other platform systems, it is recommended that the light units forming the helideck status signalling system be mounted on, or as near as possible to the helideck. Typically, maximum coverage in aziumuth will be obtained by mounting the 'main' signalling light(s) on the outboard edge of the helideck, opposite the origin of the 210° obstacle free sector (OFS). In the event that the size (essentially height) of the unit rules this location out, then a position within the LOS or down into an access/monitor platform within the OFS may be considered.

With some platform topsides it may not be possible to obtain 360° coverage in azimuth with light units mounted around the helideck and off-deck locations, possibly some distance from the helideck, may need to be considered. In this eventuality, careful consideration will need to be given to the effect of single system failures on overall system performance since light units mounted off-deck will likely not qualify as back-up for on-deck lights and vice versa; a single system failure must not lead to a significant loss of coverage in azimuth.

4.9 Practical Considerations

In arriving at a status signalling system specification, a number of factors other than the technical issues also need to be taken into consideration. In particular:

- the majority of offshore operations take place in typical day viewing conditions. Night operations normally only take place during the winter months (October through March) and represent a relatively small proportion of the overall total. Incidences of poor visibility during either night operations or in bright day conditions are therefore considered to be rare;
- the viewing conditions at offshore platforms at night will vary widely depending on the amount and intensity of the cultural lighting present and, at NUIs where the need for the status signalling system is arguably greatest, the cultural lighting environment is comparatively benign;

- a number of platforms have installed status signalling systems compliant with the earlier specification contained in CAA Paper 98003 (Reference [4]) and the 4th Edition of CAP 437 (Reference [1]). Changes from this specification have therefore only been made where considered significant.
- due account has been taken of the performance of available lighting products that are suitable for this application.

5 Discussion

5.1 Current Operational Requirement and System Specification

The original specification (see Section 4.3.6 of Reference [1]) required a main beam intensity of 700Cd for use in meteorological visibilities down to 1400m. With reference to Appendix A (see Section 4), such a light would be **detectable** at 953m in typical day viewing conditions, i.e. in excess of the stated operational requirement of 900m. In the same viewing conditions, a 700Cd light would not be **conspicuous** beyond 700m. In bright day viewing conditions a 700Cd light would be **detectable** at 700m and **conspicuous** at approximately 500m. Taking account of the practical considerations detailed in Section 4.9, the fact that most practical systems will exhibit greater conspicuity than that predicted using Allard's law (see Section 4.1), the relatively modest impact on range performance in the worst case viewing conditions, and the relatively low probability of the occurrence of the worst case viewing conditions, the existing main beam intensity requirement of 700Cd is to be retained.

The vertical beamwidth requirement varies with viewing range. Both the mean angle of elevation (middle curve in Figure 2) and the width of the beam (vertical distance between lower and upper curves in Figure 2) increase as the viewing range reduces. The shortest key viewing range requirement (above) is 500m, at which range the main beam intensity would need to be maintained from 2° to 11° in elevation to cover 95% of the approaches for which in-service data was obtained. This corresponds to the mean angle of elevation ±3 standard deviations if the data follows a normal distribution. At the longest key viewing range of 900m, the corresponding beamwidth extends from 1.4° to 8.7°. The ideal vertical beamwidth specification is therefore 1.4° to 11°. Taking account of the fact that the intensity of any practical light is unlikely to vary significantly at angles less that 1° from the main beam, the existing upper limit of 10° (see Section 4.3.6 of Reference [1]) is to be retained, and a new lower limit of 2° is to be introduced. While less than the original 5° lower limit, the new figure of 2° is unchanged from the interim guidance issued to industry in December 2003 (Ref. 6).

Outside of the main beam, the overflight (90° elevation) case is taken to represent a rational operational requirement for the purposes of system specification. Taking account of the practical considerations detailed in Section 4.9, and that this particular requirement is not considered critical as the pilot will have a second opportunity to detect the signal when approaching the platform, a requirement that the signal be **detectable** at 1500ft in meteorological visibilities down to 1400m in bright day viewing conditions, and **conspicuous** at the same range and meteorological visibility in typical day viewing conditions is to be adopted. This leads to a minimum off-beam intensity of 176Cd, which is less onerous than the earlier requirement of 215Cd.

The above requirements are summarised in Figure 3. The transition from the main beam intensity to the off-beam intensity has been designed to encompass the upper limit of the helideck elevation data in Figure 2.

The coverage of the system in azimuth must be 360° while the helicopter is either approaching or located on the helideck.

5.2 Future Operational Requirement and System Specification

As stated in Section 3, a reduction in minimum meteorological visibility from 1400m to 900m is envisaged as being a possibility in the foreseeable future. The only impact of this change in operational requirement is in respect of the intensity of the main signalling lights forming the system. With reference to Appendix A, applying the same arguments as for the present day operating limits yields a minimum main beam intensity of 1600Cd (see Appendix A Section 5) and a minimum off-beam intensity of 300Cd (see Appendix A Section 6). These requirements are summarised in Figure 4.

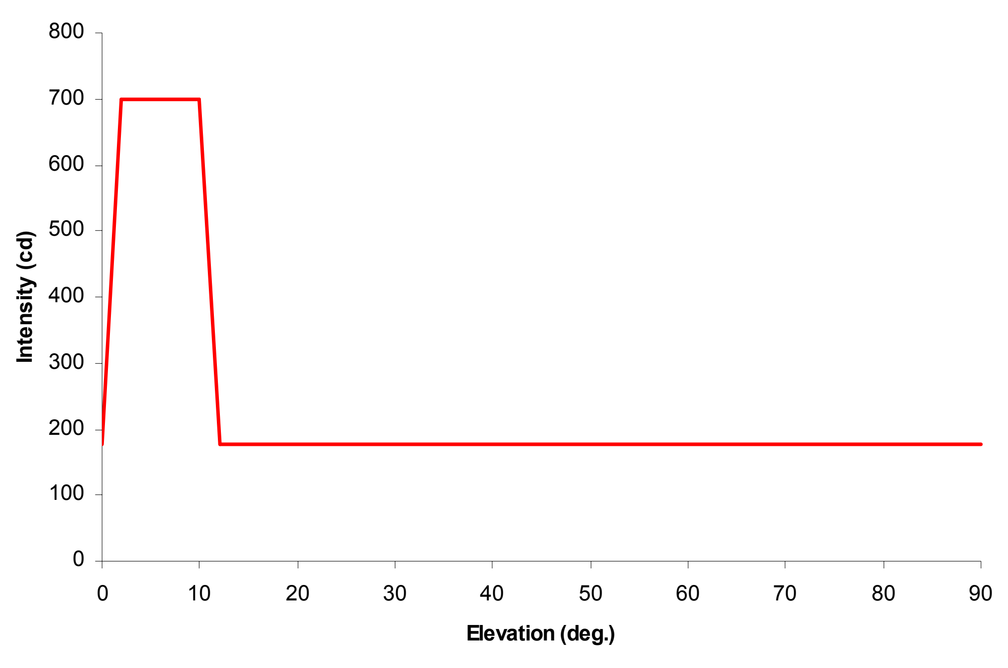


Figure 3 Vertical Beam Characteristics for Current Operating Minima (1400m minimum meteorological visibility)

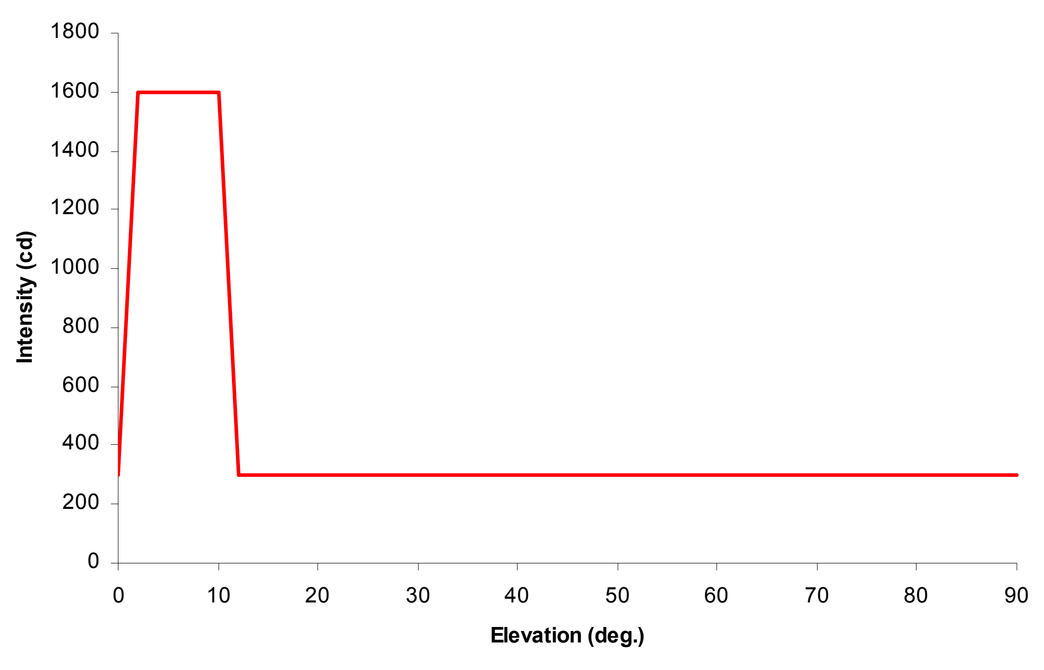


Figure 4 Vertical Beam Characteristics for Future Operating Minima (900m minimum meteorological visibility)

6 Specification

The recommended specification for the helideck status signalling system is summarised as follows:

6.1 Application

A helideck status signalling system shall be provided at all offshore helidecks where a condition can exist which may be hazardous for the helicopter or its occupants, unless alternative arrangements acceptable to the CAA and the Helideck Certification Agency (HCA) are put in place.

6.2 Location

The helideck status signalling system shall be installed either on or adjacent to the helideck. Additional lights may be installed in other locations on the platform where this is necessary to meet the requirement that the signal be visible from all approach directions, i.e. 360° in azimuth (see Section 4.8.2).

6.3 Characteristics

- The effective intensity (when measured in accordance with the test procedures contained in Appendix B) shall be a minimum of 700Cd between 2° and 10° above the horizontal and at least 176Cd at all other angles of elevation (see Section 4.1.1).
- The system shall be provided with a facility to enable the output of the lights (if and when activated) to be dimmed to an intensity of between 16 and 60Cd while the helicopter is landed on the helideck (see Section 4.1.2).
- The signal shall be visible from all possible approach directions and while the helicopter is landed on the helideck, regardless of heading, with a vertical beam spread as shown in Figure 3 (see Sections 4.2 and 4.8).
- The colour of the status light(s) shall be red as defined in ICAO Annex 14 Vol.1 Appendix 1, colours for aeronautical ground lights (see Section 4.3).
- The light system as seen by the pilot at any point during the approach shall flash at a rate of 120 flashes per minute. Where two or more lights are needed to meet this requirement, they shall be synchronised to ensure an equal time gap (to within 10%) between flashes. While landed on the helideck, a flash rate of 60 flashes per minute is acceptable, The maximum duty cycle shall be no greater than 50% (see Sections 4.4 and 4.8).
- The light system shall be integrated with platform safety systems such that it is activated automatically in the event of a process upset (see Section 4.5.1).
- Facilities shall be provided for the HLO to manually switch on the system and/or override automatic activation of the system (see Section 4.5.1).
- The light system shall have a response time to the full intensity specified not exceeding 3 seconds from start-up at all times (see Section 4.5.2).
- Facilities shall be provided for resetting the system which, in the case of NUIs, do not require a helicopter to land on the helideck (see Section 4.5.3).
- The system shall be designed so that no single failure will prevent the system operating effectively. In the event that more than one light unit is used to meet the flash rate requirement, a reduced flash frequency of at least 60 flashes per minute is considered acceptable in the failed condition for a limited period (see Sections 4.7 and 4.8).
- The system and its constituent components light shall comply with all regulations relevant to the installation (see Sections 4.6 and 4.7).

- Where supplementary 'repeater' lights are employed for the purposes of achieving the 'on deck' 360° coverage in azimuth, these should have a minimum intensity of 16Cd and a maximum intensity of 60Cd (see Section 4.8.1).

6.4 Operational Procedures

The procedures to be followed by the helicopter pilot in the event of the status light system being activated either during the approach, or while the helicopter is landed on the helideck, shall be common for all platforms. The helicopter operators have established suitable procedures and enquiries related to the operating protocol should be addressed to the helicopter operators or to the HCA.

7 References

[1] CAP 437 – Offshore Helicopter Landing Areas – Guidance on Standards - 4th Edition, September 2002.

[2] CAA Paper 92006 – Offshore Platform Identification Signs - April 1992.

[3] CAA Paper 93020 – Helideck Status Signalling System - September 1993.

[4] CAA Paper 98003 – Specification for an Offshore Helideck Status Signalling System - December 1998.

[5] TNO Human Factors report ref. TM-02-C003.

[6] Interim guidance on helideck status lights on offshore installations and vessels issued by the CAA Safety Regulation Group, Flight Operations Inspectorate (Helicopters), Letter reference 10A/253/16/2B, dated 31st December 2003.

8 List of Abbreviations

ATEX	Atmosphere Explosiv (EU Directive)
Cd	Candela
CAA	Civil Aviation Authority
CIE	Commission Internationale de L'Eclairage (International Commission on Illumination)
cm	Centimeter
DERA	Defence Evaluation and Research Agency
HCA	Helideck Certification Agency
HLO	Helicopter Landing Officer
HSE	Health and Safety Executive
Hz	Hertz
ICAO	International Civil Aviation Organisation
kt	knots
LOS	limited obstacle sector
m	meter
NM	nautical mile
NUI	normally unattended installation
OFS	obstacle free sector
SRG	Safety Regulation Group (of the UK CAA)

Appendix A Calculations of Required Intensity for a Warning Light System

1 Introduction

Allard's law will be used to estimate the intensity required for seeing a light.

The equation used to define Allard's Law is:

$$E_t = I/R^2 \cdot e^{-\sigma R}$$

Where E_t = Eye Illumination threshold (lux).

The value of Et depends on the background brightness and the probability of detection. For a bright day Et = 10-3.5, for a typical day Et = 10-4.0 and for a typical night Et = 10-6.0. These values have been associated with operations to Precision Approach runways (see Attachment D to ICAO Annex 3) and are used in the absence of data relevant to offshore platforms.

I = Intensity of the light unit (Candelas).

σ = Extinction coefficient (m^{-1}). This represents the atmospheric attenuation.

R = Visual range of a light in the specified conditions of E_t and σ.

Meteorological Visibility or Met Vis (M)

As defined in Attachment D to ICAO Annex 3 this relates to a dynamic viewing situation such as when a pilot is approaching a runway in mist, or fog and specifies a contrast threshold of 5%. This gives rise to a relationship to extinction coefficient of:

$$\sigma = 2.996/M$$

The intensity value that will be obtained from the above is that required for the light to be just visible. A warning light needs to stand out from the background rather than be just detectable. A practical way to improve conspicuity, at the detection range, is to increase the threshold intensity by half an order (i.e. multiply by 3.16).

NOTE: The intensities generated by Allard's Law are independent of the colour of the light. No allowance for the response of the human eye to light of different wave lengths is required in the intensities quoted as this is normally accounted for in the characteristics of the photometer used to measure the light under test.

2 Intensities for Required Visual Ranges in a Meteorological Visibility of 1400m

Given a value of M = 1400 then $\sigma = 2.996/1400\ m^{-1}$. Table 1 summarises the required effective (flash) intensity for a warning light under different viewing conditions.

Table 1

Conditions for viewing lighting	E_t (lux)	Required intensity (cd) for a detectable light at 900m	Required Intensity (cd) for a conspicuous light at 700m
Bright day	$10^{-3.5}$	1758	2192
Typical day	$10^{-4.0}$	556	693
Typical night	$10^{-6.0}$	~6	~7

3 Intensities for a Required Visual Range of 1500ft (457m) in a Meteorological Visibility of 1400m

Given a value of M = 1400 then $\sigma = 2.996/1400\ \mathrm{m}^{-1}$. Table 2 summarises the required effective (flash) intensity for a warning light under different viewing conditions.

Table 2

Conditions for viewing lighting	E_t (lux)	Required intensity (cd) for a detectable light at 457m	Required Intensity (cd) for a conspicuous light at 457m
Bright day	$10^{-3.5}$	176	~556
Typical day	$10^{-4.0}$	56	176
Typical night	$10^{-6.0}$	~1	~2

4 Visual range of Light of 700cd in a Meteorological Visibility of 1400m

Given values of $I = 700$ and $\sigma = 2.996/1400\ \mathrm{m}^{-1}$, Table 3 summarises the achieved visual range for a warning light under different viewing conditions.

Table 3

Conditions for viewing lighting	E_t (lux)	Detectable range (m) for a light of 700cd	Conspicuous range (m) for a light of 700cd
Bright day	$10^{-3.5}$	701	494
Typical day	$10^{-4.0}$	953	701
Typical night	$10^{-6.0}$	2288	1916

It is noted that the term Meteorological Visibility (M), is meaningless at night and it is assumed that the equivalent daylight value is that implied.

5 Intensities for Required Visual Ranges in a Meteorological Visibility of 900m

Given a value of M = 900m then $\sigma = 2.996/900\ \mathrm{m}^{-1}$. Table 4 summarises the required effective (flash) intensity for a warning light under different viewing conditions.

Table 4

Conditions for viewing lighting	E_t (lux)	Required intensity (cd) for a detectable light at 900m	Required intensity (cd) for a conspicuous light at 700m
Bright day	$10^{-3.5}$	5118	5034
Typical day	$10^{-4.0}$	1618	1592
Typical night	$10^{-6.0}$	16	16

It is noted that the term Meteorological Visibility (M), is meaningless at night and it is assumed that the equivalent daylight value is that implied.

6 Intensities for a Required Visual Range of 1500ft (457m) in a Meteorological Visibility of 900m

Given a value of M = 900 then $\sigma = 2.996/900\ m^{-1}$. Table A-5 summarises the required effective (flash) intensity for a warning light under different viewing conditions.

Table 5

Conditions for viewing lighting	E_t (lux)	Required intensity (cd) for a detectable light at 457m	Required intensity (cd) for a conspicuous light at 457m
Bright day	$10^{-3.5}$	302	956
Typical day	$10^{-4.0}$	96	302
Typical night	$10^{-6.0}$	1	3

Appendix B Flashing Light Test Procedure

1 Introduction

The purpose of this appendix is to specify a procedure for testing flashing lights to be used as a standard by manufacturers and test houses to ensure compliance with the helideck status light photometric specification. The procedure has been produced by collating requirements from existing advisory material and known standards into one document, and is based on the flashing light test procedure contained in Reference [1].

The performance of a light is specified by the intensity distribution. To show compliance with any particular specification, it is necessary to make measurements of intensity at different angles of azimuth and elevation. The techniques for conducting measurements on steady burning lights are well established and for flashing lights many of the same considerations apply. However, the flash characteristic requires some modifications to the test procedures that are employed.

Flashing lights, in the context of this appendix, are those lights where the light signal is discontinuous. This may be achieved through the electrical switching of the source (e.g. tungsten filament), or by the mechanical occulting of a steady burning light. The latter method generally produce flashes that are significantly longer than those achieved with discharge lights, which can produce flashes of very short duration (e.g. 1 to 10 milliseconds).

2 Objective

The objective of the test shall be to measure the effective intensity of the light over the range of operationally required angles in both elevation and azimuth with an overall accuracy of better than 10%.

3 Requirements

The following constitute the requirements in respect of the various aspects of testing.

3.1 Dark Room Requirement

Measurements should be made in a dark room environment. The construction of the dark room should be such that the influence of multiple reflections on the measurement values obtained is kept to an absolute minimum. Evidence of the level of spurious light present shall be supplied to the competent authority.

3.2 Equipment Operating Requirement

The test light should be installed and operated in compliance with the normal installation guidelines for that equipment. An electrical supply providing the specified voltage, or current, and frequency should be used. Where appropriate, cables should replicate the capacities and lengths to be used in service. The latter is particularly important where a light unit and the associated control gear are not co-located. The characteristics of the electrical supply at the unit shall be provided to the competent authority.

3.3 Inverse Square Law Requirement

Since measurements of illuminance are to be made, the distance between the photometer and the light under test should be such that the inverse square law, relating intensity to illumination, is obeyed. That is to say the distance between the light under test and the photometer must be such that the intensity calculated from illuminance is unaffected by a change in distance. Evidence of conformity to the inverse square law shall be supplied to the competent authority.

Information

In these circumstances, the illuminance at the photometer is solely proportional to the intensity and the constant of proportionality is equal to the inverse of the square of the distance between the light and the photometer.

$$E = \frac{I}{R^2}$$

Where: E is the illuminance at the photometer (lux)

I is the intensity of the light (candela)

R is the distance between the light and the photometer (metres)

Compliance with this requirement can be demonstrated by making measurements at a number of distances, and demonstrating that the distance to be used for the verification testing is equal to, or greater than, the distance at which the computed intensity becomes independent of the distance used. The light and photometer may be mounted on some form of track or rail to facilitate this.

The distance at which compliance is achieved is a function of both the aperture and beam spread of the light under test. The greater the aperture and the smaller the beamspread, the greater will be the distance required. For the majority of aviation ground lighting equipments this distance will need to be approximately 20-30 metres. An alternative means of estimating an acceptable measurement distance assumes the minimum range to be 100 times the aperture of the light under test. Further information can be found at Reference [3].

3.4 Angular Sampling Requirement

The light output shall be sampled over an orthogonal grid in elevation and azimuth. The sample interval in elevation shall be no less than 5% of the beam width (in elevation), or at a 1° interval, which ever is the lesser. If the former, then the azimuth axis is to be sampled at 5% of the beam width in azimuth; if the latter then at 10° intervals over the range of elevation angles which are operationally significant. The data shall be supplied to the competent authority.

For the present purpose, the beam width in each axis, is defined as the angle containing the peak of intensity, subtended by the points either side of the peak where the intensity falls to 3% of the value at the peak.

Information

It is recommended that the light under test be installed on a Goniometer so that its angular position in relation to the photometer can be readily and repeatedly adjusted.

Where a beam has dimensions of approximately ± 10°, in azimuth and elevation, the intensity measurements would be made using the grid pattern shown in Figure 1. This figure can also be found in Reference [4].

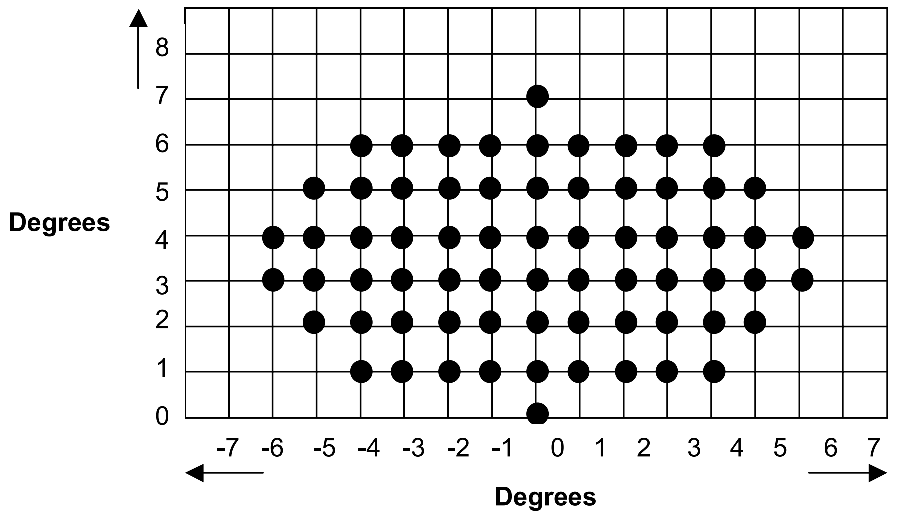


Figure 1 Typical Intensity Distribution Measurement Diagram

3.5 Photometer Aperture Requirement

The measured intensity angular distribution of the light shall not be affected by the angle subtended by the aperture of the photometer at the light. The aperture of the photometer shall be such that it subtends an angle at the light no greater than half of the angular sampling interval employed in Section 3.4.

3.6 Angular Positioning Requirement

The angular position of the light under test with respect to its datum axes shall be known to within an angle no greater than half of the angular sampling interval employed in Section 3.4.

3.7 Photometer Spectral Response Requirement

The output from the unit under test shall be measured using a photometer having a spectral response conforming to the 1931 CIE Standard Observer curve for photopic vision (Reference [5]). Evidence of conformity shall be supplied to the competent authority.

3.8 Photometer Temporal Response Requirement

The temporal response of the photometer should not introduce an error of more than 5% in the measurement of the effective intensity of the flash. Evidence of the accuracy achieved shall be supplied to the competent authority.

3.9 Flash Repeatability Requirement

The intensity at each point on the grid should be the average of at least 5 flashes. The typical flash to flash dispersion in intensity shall be recorded and supplied to the competent authority.

4 Calculation of Effective Intensity

The effective intensity of all flashing lights to be used as helideck status lights (regardless of flash duration) will be defined using the modified-Allard method (see Appendix C).

Since the modified-Allard method has been specifically designed to produce the same results as the Blondel-Rey method for rectangular pulses, the effective intensity of helideck status lights having a rectangular flash profile may be defined using the Blondel-Rey method (References [2], [6] and [7]).

5 References

[1] Puffett, A., A Generic Test Procedure for the Measurement of Flashing Lights, QinetiQ Report Ref. QINETIQ/FST/CSS/CR011654, Issue M dated 07 May 2002.

[2] International Civil Aviation Organisation Visual Aids Panel Working Paper, VAP/ 13 – WP/ 33, 1997, Measurement of Intensity for Steady Burning and Flashing Lights

[3] Moerman, J. J. B. & Holmes, J. G., The Choice of Test Distance to Control Errors in the Photometry of Round Projectors Focused at a Long Distance, Lightning Research and Technology, Volume 13, No 2, 1981

[4] International Civil Aviation Organisation International Standards and Recommended Practices, Annex 14 Volume 1, Aerodrome Design and Operations, Second Edition, 1995

[5] International Commission on Illumination (CIE), Standard Observer & Co-ordinate System, Eighth Session, (1931), Publication No 15, Colorimetry, 1971

[6] Douglas, C. A., Computation of the Effective Intensity of Flashing Lights, Illuminating Engineering Society, Volume 53, p600, November. 1958

[7] Illuminating Engineering Society Guide for Calculating the Effective Intensity of Flashing Signal Lights, Volume 59, p747, November 1964

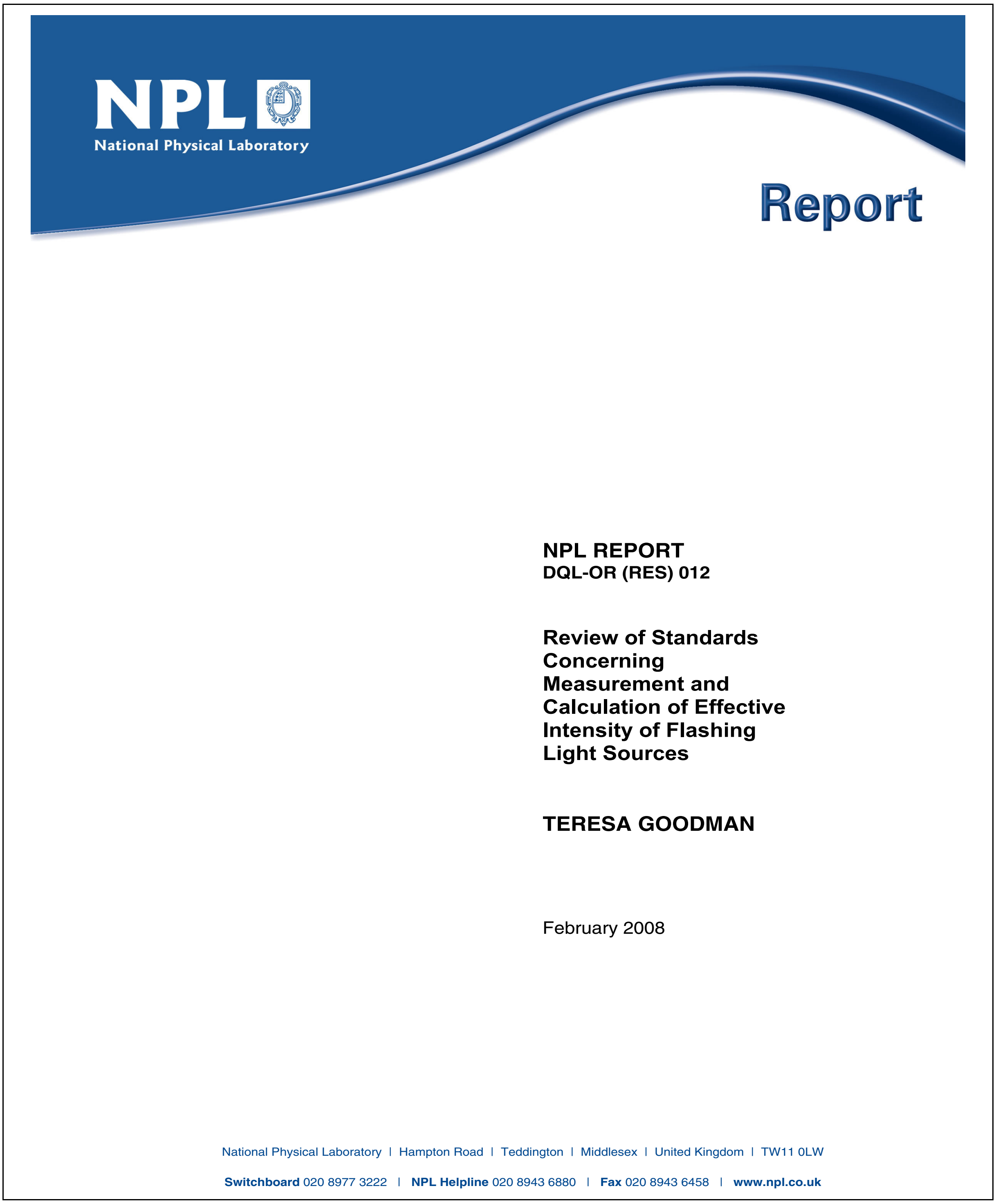
6 Bibliography

1 Federal Aviation Administration, Advisory Circular 20-74, Aircraft Position and Anti-Collision Light Measurements

2 International Commission on Illumination (CIE), Draft Technical Report on the Effective Intensity of Flashing Lights

Appendix C Review of Standards Concerning Measurement and Calculation of Effective Intensity of Flashing Light Sources – NPL Report Ref. DQL-OR(RES)012, February 2008

This appendix contains an unabridged copy of the above report and constitutes the technical justification for the method of testing helideck status lights specified in this document. The NPL report was circulated to the Helideck Certification Agency by the CAA Safety Regulation Group, Flight Operations Inspectorate (Helicopters), under letter ref.10A/253/16/2E, dated 6th March 2008.



NPL
National Physical Laboratory

Report

NPL REPORT
DQL-OR (RES) 012

Review of Standards Concerning Measurement and Calculation of Effective Intensity of Flashing Light Sources

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February 2008

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CONTENTS

Review of Standards Concerning Measurement and Calculation of Effective Intensity of Flashing Light Sources

1. BACKGROUND

This report has been prepared by the National Physical Laboratory (NPL) for the Civil Aviation Authority (CAA) under contract number 1248. It provides a review of the methods and procedures for the measurement and calculation of the effective intensity of flashing light sources that are currently specified in standards and recommendations for the transportation sector. It also addresses some specific issues related to the adoption of new lighting technologies, such as LEDs, which may require clarification with regard to their compliance under existing standards; in particular, consideration is given to the question: When can the effective intensity of a flashing light be determined by treating it as being equivalent to a steady light?

2. INTRODUCTION

Flashing lights are widely used in many signalling applications in aviation, marine, and land transportation due to the fact, recognised since the 19th century, that a flashing light has a higher detectability and conspicuity than a steady light of the same average intensity. The detectability and conspicuity of these lights is known to depend on many factors, including the number of flashes in a given time, the peak intensity, and the waveform of each flash.

Unlike a steady light, the light output with time for a flashing light is not continuous. On the contrary, it may have a very complex waveform, possibly with each visible flash being composed of several short, usually (but not necessarily) regularly spaced, flashes, sometimes called flicks. Although the average intensity for any waveform can be readily calculated, as indicated above this does not correlate with the visibility of the light. The concept of "effective visual intensity" has therefore been introduced to provide a measure of the apparent light output. This is defined by the International Commission on Illumination (CIE) as:

> "The luminous intensity of a fixed light, of the same relative spectral distribution as the flashing light, which would have the same luminous range (or visual range in aviation terminology) as the flashing light under identical conditions of observation."[1]

The CIE goes on to note that: "For practical purposes, a conventional effective intensity may be evaluated for a flashing light from photometric data by an agreed method." Thus standards and recommendations for flashing lights, such as aircraft anti-collision lights, marine aids-to-navigation lights, obstruction lights, and emergency vehicle warning lights, generally include a specification of the effective intensity which must be achieved, calculated using a specified method. There is, however, no generally agreed method at present for determination of effective intensity and different standards therefore use different methods. Four methods are in widespread use (the methods of Allard[2], Blondel-Rey[3] and Douglas[4], and Schmidt-Clausen[5, 6]) and a fifth has recently been proposed (modified-Allard method[7]).

3. METHODS FOR CALCULATING EFFECTIVE INTENSITY

3.1 Allard Method

The first method was proposed by Allard in 1876 and assumes that the visual sensation for the human eye, $i(t)$, for a flashing light with instantaneous intensity $I(t)$ is given by:

$$\frac{di(t)}{dt} = \frac{I(t) - i(t)}{a} \qquad \text{Equation 1}$$

where a is a visual time constant which is usually taken to have a value of 0.2 s.

This differential equation indicates an exponential decay of $i(t)$ with the visual time constant, a, and it can be solved by taking a mathematical convolution of $I(t)$ with a visual impulse function, $q(t)$, such that:

$$i(t) = I(t) \otimes q(t); \quad q(t) = \frac{1}{a} e^{-\frac{t}{a}} \ (t \geq 0) \qquad \text{Equation 2}$$
$$q(t) = 0 \, (t < 0)$$

where $\otimes$ means ‘convolution’.[*]

The effective intensity is then defined as the maximum value of $i(t)$.

This method has not found wide application, partly because of the difficulty in carrying out the calculations before the advent of the computer, although the construction of a suitable detector is possible.

3.2 Blondel-Rey and Blondel-Rey-Douglas Method

In 1911, Blondel and Rey proposed that the effective intensity, I_{eff}, of a flashing light can be described by the equation:

$$I_{eff} = \frac{\int_{t_1}^{t_2} I(t)dt}{a + (t_2 - t_1)} \qquad \text{Equation 3}$$

where $I(t)$ is the instantaneous luminous intensity of the flash, $(t_2 - t_1)$ is the duration of the flash, and a is a visual time constant similar to that described above, which is again usually taken to have a value of 0.2 s.

---

[*] The convolution of two functions *f* and *g* is defined as the integral of the product of the two functions after one is reversed and shifted.

This equation is straightforward for application to rectangular pulses, but t_1 and t_2 are difficult to determine for a pulse with slow rise and decay. Blondel and Rey proposed that for any pulse waveform, t_1 and t_2 should be determined in such a manner that:

$$I_{eff} = I(t_1) = I(t_2) \qquad \text{Equation 4}$$

is satisfied by equation 3 above. This leads to the result:

$$\int_{t_1}^{t_2} (I(t) - I_{eff})dt = a I_{eff} \qquad \text{Equation 5}$$

This equation can be solved by iterative calculation, although this again posed a computational problem until the advent of computers.

In 1957, Douglas proved that the condition given in equation 5 is achieved when I_{eff} is maximised. He also proposed that, for a train of pulses, the effective intensity could be determined by the so-called Blondel-Rey-Douglas formulation:

$$I_{eff} = \frac{\int_{t_1}^{t_a} I(t)dt + \int_{t_a}^{t_2} I(t)dt}{a + (t_2 - t_1)} \qquad \text{Equation 6}$$

3.3 Form-Factor Method

Schmidt-Clausen introduced the concept of "Form Factor" in 1968, and proposed a method that simplified the calculation of effective intensity for non-rectangular pulses. The method defines the effective intensity of a flashing light, I_{eff}, as:

$$I_{eff} = \frac{I_{max}}{1 + \frac{a}{FT}}; \quad F = \frac{\int_0^T I(t)dt}{I_{max}T} \qquad \text{Equation 7}$$

where F is called the Form Factor, T is the total measurement time and I_{max} is the maximum value of the instantaneous effective intensity $I(t)$. This equation can be rewritten in the form:

$$I_{eff} = \frac{\int_0^T I(t)dt}{a + \Delta t}; \quad \Delta t = \frac{\int_0^T I(t)dt}{I_{\max}} = FT \qquad \text{Equation 8}$$

which can be interpreted as an extension of the Blondel-Rey equation with a different method for the determination of the duration of the flash.

3.4 Modified-Allard Method

A modification to the Allard method has been proposed by Couzin and Ohno, which theoretically solves some inherent problems in the Form Factor method and Blondel-Rey equation[7]. This method defines the effective intensity of a flashing light, I_{eff}, as the maximum value of $i(t)$ where:

$$i(t) = I(t) \otimes q(t); \quad q(t) = \frac{a}{(a+t)^2} \quad ; \quad a = 0.2 \qquad \text{Equation 9}$$

$\otimes$ means ‘convolution’.

The visual impulse response function $q(t)$ can be approximated by:

$$q(t) = \frac{w_1}{a_1} e^{-\frac{t}{a_1}} + \frac{w_2}{a_2} e^{-\frac{t}{a_2}} \qquad \text{Equation 10}$$

where the coefficients a_1, a_2, w_1 and w_2 are obtained by optimisation such that the result of the calculation for rectangular pulses is the same as that obtained using the Blondel-Rey equation, while keeping the total time constant equal to 0.2 s and the effective intensity, I_{eff}, for a steady light equal to I_{max}. The coefficients are linked to each other as follows:

$$\frac{w_1}{a_1} + \frac{w_2}{a_2} = \frac{1}{a}, \; w_1 + w_2 = 1, \; a = 0.2 \; s$$

One of the solutions for the optimisation[7] is a_1=0.113, a_2=0.869, w_1=0.5, w_2=0.5.

It should be noted that the modified-Allard method has been specifically designed to give the same results as the Blondel-Rey method for rectangular pulses.

3.5 Comparison of Results for Complex Waveforms Using Different Methods

The effective intensity calculated using any of the above methods depends on the waveform of the light source being measured and, depending on the precise details of this waveform, the methods can all give very different results. For example, a major deficiency of the Allard method is that it does not work well for rectangular pulses, giving results that are much higher (20% - 30% higher) than those obtained using either the Blondel-Rey or Form-Factor methods. This problem of inconsistencies in calculated effective intensity has become more acute in recent years, as new technologies have been introduced into signalling applications. This is because the flash profiles of modern light sources can differ greatly from those of traditional sources, which were generally based on tungsten lamps used in a rotating optic. For example, metal halide lamps are sometimes used, supplied from a low frequency sinusoidal AC source, which gives a cyclic light output at twice the frequency of the supply. In a rotating optic, this 100 Hz waveform is superimposed on the Gaussian flash profile. An example of this is shown in Figure 1.

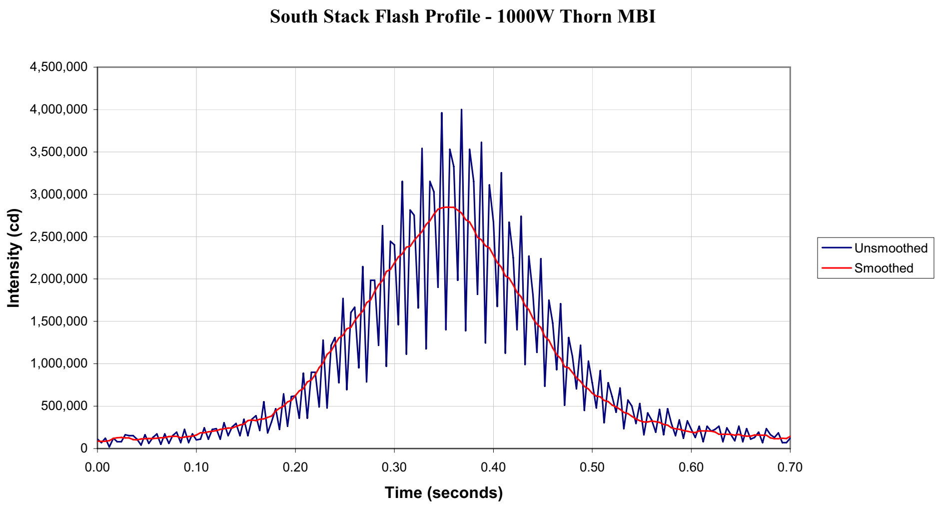
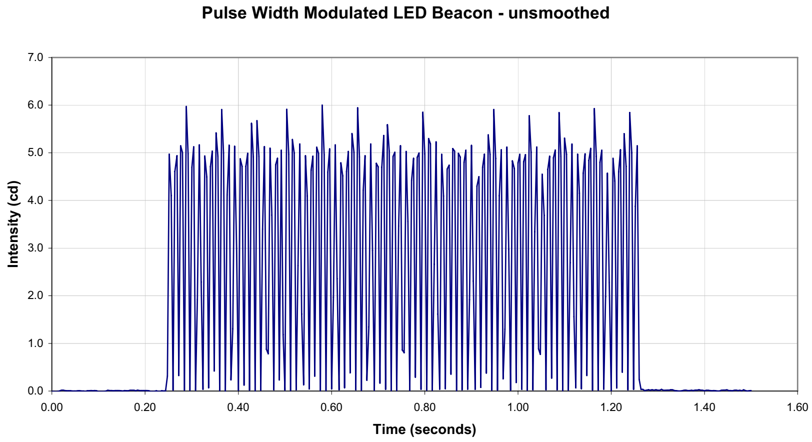


Fig. 1. Flash profile for a first order rotating optic with six lens panels and a 1000 W metal halide lamp supplied with 240 V, 50 Hz AC.

The effective intensity and pulse duration determined for such a source can vary significantly, depending on which of the different methods of calculation is used (see Tables 1 and 2). Furthermore, the measurement equipment used can also affect the results; often, for example, some smoothing of the profile is introduced, as shown by the red curve in Figure 1 and by the calculated results in Tables 1 and 2.

LED beacons can have even more complex waveforms. Although some LEDs give a very rectangular flash profile, others are pulse width modulated in order to regulate power (see Figure 2, top) and some have sharp spikes on the leading edge of the flash, which are probably a function of the power supply regulation (see Figure 2, bottom). The very rapid frequency with which the output for such sources changes can pose particular problems for measurement instrumentation and some smoothing of the profile often occurs, as shown in Figure 3.



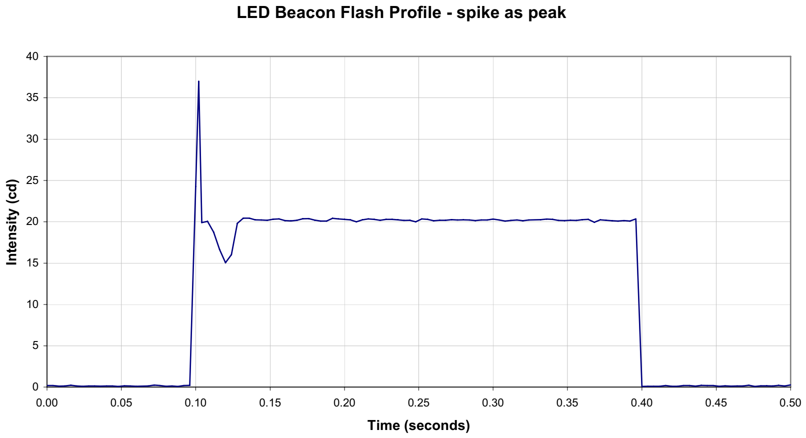


Fig.2. Examples of the flash profiles (unsmoothed) for two types of LED beacon. Top: pulse width modulated beacon with 1 s contact closure time (CCT), bottom: LED beacon with spike on leading edge, 0.3 s CCT.

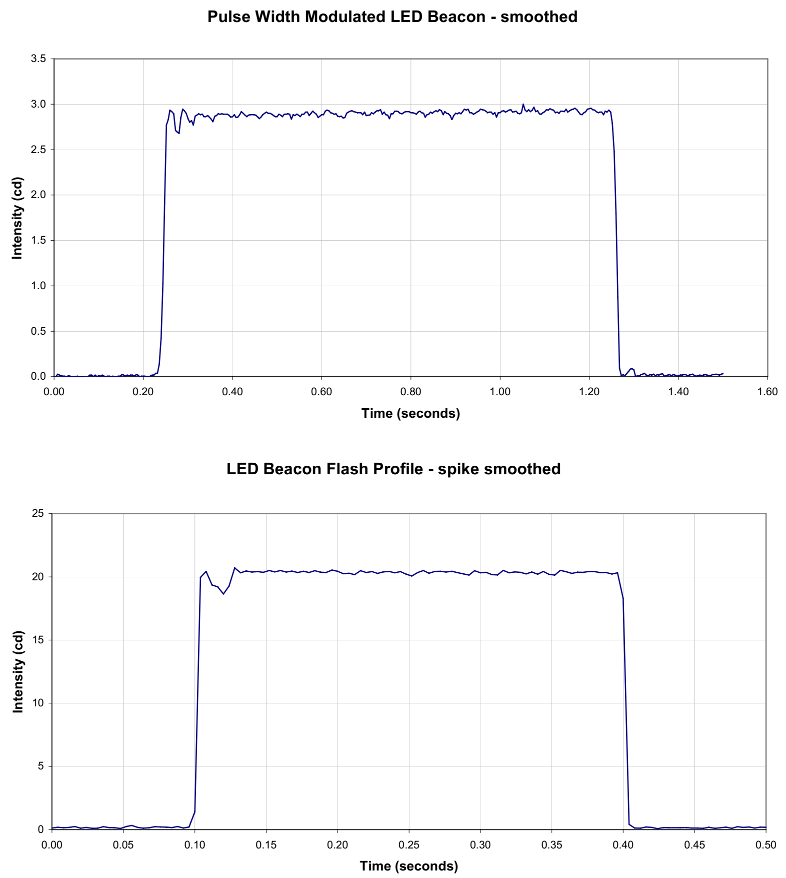


Fig. 3. Typical flash profiles measured using equipment that ‘smoothes’ the profile, for the two LED beacons shown in Fig. 2.

The results of using different methods to evaluate the effective intensity and flash duration for the flash profiles shown in Figures 1 and 2/3 are shown in Tables 1 and 2. The methods used for effective intensity are those given in BS 942 (Blondel-Rey) and IALA 1980 (Schmidt-Clausen). The methods for flash duration are those in BS 942 ($t_{90\%}$), IALA 1980 ($t_{50\%}$) and IALA 2001 (Δt determined using the Schmidt-Clausen method). Significant differences are apparent in the results obtained using the various calculation methods and depending on whether the profile is, or is not, smoothed by the measurement instrumentation.

Flash Details		Peak Intensity Io (cd)	Integrated Intensity J (cd.sec)	Effective Intensity (cd)	
				BS942	IALA 1980
Metal halide	unsmoothed	4,012,000	642,125	2,933,505	1,783,428
	smoothed	2,856,626	640,172	2,104,882	1,509,481
LED beacon, 1s CCT	unsmoothed	6.00	3.16	5.43	4.35
	smoothed	3.00	2.95	2.73	2.49
LED beacon with spike	unsmoothed	37	6.20	0.18	17
	smoothed	21	6.12	15.00	12

Table 1. Calculation of effective intensity using different methods.

Flash Details		BS942	IALA 1980	IALA 2001
		$t_{10\%}$	$t_{50\%}$	Δt
Metal halide	unsmoothed	0.408	0.180	0.160
	smoothed	0.420	0.192	0.224
LED beacon, 1s CCT	unsmoothed	0.592	1.004	0.527
	smoothed	1.000	1.012	0.984
LED beacon, with spike	unsmoothed	<0.001	0.296	0.168
	smoothed	0.292	0.296	0.295

Table 2. Calculation of flash duration using different methods.

Clearly, therefore, it is essential in all standards and recommendations for signalling applications to specify not only the minimum effective intensity that must be produced by a flashing light, but also the measurement and calculation methods to be used to determine this effective intensity.

4. EFFECTIVE INTENSITY AS APPLIED IN SIGNALLING STANDARDS

4.1 Method Used for Calculating Effective Intensity

As shown in Table 3 below, the Blondel-Rey equation or its extended form, Blondel-Rey-Douglas, is the most widely accepted method in most application areas. The Form Factor method has more recently been adopted in some standards, whereas the Allard method is usually only recommended for a train of pulses. None of these methods has so far been adopted by the CIE, although work is underway in CIE TC2-49 Photometry of Flashing Light to develop recommendations for the measurement of pulsed and flashing sources (see Section 5).

Standards using Blondel-Rey or Blondel-Rey-Douglas Method
International Civil Aviation Organization (ICAO) Aerodrome Design Manual, Part 4
Civil Aviation Authority (CAA) Safety Regulation Group CAA Paper 2003/06 2004 Specification for an Offshore Helideck Status Light System
Amendments to Annex 14, Volumes I and II, and updated guidance materials in the Aerodrome Design Manual, Part 4 - Visual Aids Output Date 2009-12-15 International Civil Aviation Organization meeting April 2007
Medium and low intensity LED obstruction lights ICAO Annex 14, chapter six - Visual aids for denoting obstacles
FAA Ad.Cir. 150/5345-43E - Specification for obstruction lighting equipment
Joint Aviation Authorities JAR-25 Large Aeroplanes
Joint Aviation Authorities JAR-295 Large Rotorcraft
SAE ARP 5029 Measurement Procedure for Strobe Anti-collision Lights
SAE AS 8017A Minimum Performance Standard for Strobe Anti-collision Lights
International Maritime Organization (IMO) 1972 Convention on the International Regulations for Preventing Collisions at Sea
The Maritime Safety Committee Resolution MSC.200(80) Adoption of Amendments to the Revised Recommendation on Testing of Life-Saving Appliances
European Committee for Standardisation CEN EN 14744 Inland navigation vessels and sea-going vessels – Navigation Light
Economic Commission for Europe Inland Transport Committee Further Amendments to the European Code for Inland Waterways (CEVNI) 2007 Annex 5 - Intensity and range of signal lights on vessels
1995 US Dept Transport Federal Railroad Administration Safety of Highway-Railroad Grade Crossings: Use of Auxiliary External Alerting Devices to Improve Locomotive Conspicuity
Standards using Form-Factor Method
International Association of Lighthouse Authorities (IALA) E-122 Recommendation on the Photometry of Marine Aids to Navigation Signal Lights, 2001
IALA Recommendations for Calculation of Effective Intensity of Rhythmic Lights, 1980
United Nations E/ECE/324 Uniform Provisions Concerning the Approval of Special Warning Lights for Motor Vehicles
Standards not Specifying a Particular Method
IALA Recommendations on Determination of Luminous Intensity of a Marine AID TO Navigation Light, 1977

Table 3. Methods used for determination of effective intensity in standards for signalling applications in the transportation sectors.

4.2 When Can a Flashing Light be Treated as a Fixed Light?

The majority of standards provide no guidance regarding the maximum pulse duration for which the given method for determination of effective luminous intensity should be taken to apply. The implication in these cases is that the method should be used in all situations where the light is intended to be seen as a flashing light i.e. where the duration of light in a period is clearly distinct from the duration of darkness.

In a small number of cases, however, a maximum pulse duration is specified (see Table 4) although it is important to note that there is no evidence given in any of these standards to justify the value for the maximum flash duration that has been chosen. The statements in those standards specifying a maximum pulse duration take one of four forms:

a) "For some lights, the time duration of flash can be sufficiently long that the error is not significant if the flashing mechanism is disabled and the intensity is measured with the light operating in steady burning mode. This would be the case when the time duration of flash is more than 200 ms (0.2 s)."
b) "Flashing lights with a flash duration of not less than 0.3 seconds, not including incandescence time, may be considered as fixed lights for the measurement of luminous intensity. (Incandescence time is the time interval between switch on and the luminous intensity reaching the required minimum luminous intensity.)"
c) "If the duration of the light phenomenon less the rise time and decay time, i.e. the time in which the instantaneous luminous intensity attains or exceeds the required minimum luminous intensity, is greater than 0.3 s, the light may be regarded as a steady light. The effective luminous intensity shall not then be determined."
d) "The effective intensity of a flashing light for any flash having a duration of less than 0.15 seconds, will be defined using the Blondel-Rey relationship."

Standard	Form of Statement
International Civil Aviation Organization (ICAO) Aerodrome Design Manual, Annex 14 Part 4	a
The Maritime Safety Committee Resolution MSC.200(80) Adoption of Amendments to the Revised Recommendation on Testing of Life-Saving Appliances	b
European Committee for Standardisation CEN EN 14744 Inland navigation vessels and sea-going vessels – Navigation Light	c
Civil Aviation Authority (CAA) Safety Regulation Group CAA Paper 2003/06 2004 Specification for an Offshore Helideck Status Light System	d
Economic Commission for Europe Inland Transport Committee Further Amendments to the European Code for Inland Waterways (CEVNI) 2007 Annex 5, "Intensity and range of signal lights on vessels"	c

Table 4. Standards making reference to a maximum flash duration for the determination of effective intensity.

As described in Section 3, several methods have been formulated to describe the response of the human visual system to time varying stimuli. These, and most other, laws of visual perception are empirically derived, based on experimental investigations in which various parameters may be varied, including the intensity of the stimulus, its duration, its position in the visual field, and the background conditions. From such experimental studies it is apparent that at short pulse durations the threshold intensity and stimulus duration obey some sort of reciprocal relationship; a stimulus of low intensity may be detectable provided that it is presented for a sufficiently long period of time, whereas a higher intensity stimulus will only need to be presented for a short period of time in order to be seen. This reciprocity forms the basis for all the methods for determining effective intensity described earlier, coupled with a gradual fall-off in visual effectiveness as the pulse duration increases. It must be noted, however, that none of these methods specify a maximum pulse duration for which they can or should be applied.

From a physiological standpoint, there likewise appears to be no evidence in the scientific literature to indicate a mechanism within the human visual system that would lead to a step change in the perceived intensity of a flash of light above a certain flash duration; rather a gradual fall-off in the visual effectiveness with pulse duration is expected[8]. For very short flash durations, the photochemistry of the pigments in the retina is the dominating factor and the ability to perceive a flash is determined simply by the product $I.t$ where I is the intensity and t the duration. This holds for values of t up to a certain limit, which may vary from 2 ms to 100 ms depending on the conditions (position in visual field etc.). For longer exposure times, the summation of the flash of light due to bleaching of the retinal photopigment is only partial (i.e. the pigment starts to be replenished before the flash of light ends) and the perceived intensity increases less rapidly with exposure time than does $I.t$. Finally, for time periods of a few seconds, it is only the light intensity that is important. At this latter point, the eye is in an equilibrium state, in which the speed of decomposition (bleaching) of the photopigments due to the incident light is the same as the speed of synthesis of the pigment in the retina.

The question then arises, what is the basis for the limits currently given in some of the standards (0.15 s, 0.2 s or 0.3 s)? There are several possible explanations for these limits, including:

1. A limit set by the specified maximum pulse repetition rate and duty cycle e.g. a maximum repetition rate of 5 Hz and a duty cycle of 1:1 will lead to a maximum possible flash length of 100 ms.
2. A limit set by the technologies available at the time the standard was first written e.g. a maximum speed of rotation for a beacon using a tungsten lamp and mask.
3. A possible misinterpretation of statements in other standards relating to the influence of pulse rise and fall times on the calculated effective intensity values.
4. Propagation of limits from one standard to another, without consideration of the applicability (e.g. duplication of a limit based on maximum pulse repetition rate and duty cycle for one application into another application for which the same pulse repetition rate and duty cycle does not apply).

Only those directly involved in the preparation of the relevant standards are likely to know the origin of any particular limit. Nevertheless, in the opinion of the authors of this report, it appears unjustifiable, in terms both of the mathematics of the models used and the physiology of the eye, to limit the methods for determination of visual effectiveness to a certain (relatively short) pulse length. Rather it would appear logical to base any limit on the size of the step change in the calculated effective intensity which is considered reasonable or acceptable e.g. 10% or 20%.

4.2.1 Effect on Calculated Effective Intensity Values

Since the Blondel-Rey formula is the most widely used of the various methods for calculation of effective intensity, we will use this as the basis for further discussion. The arguments presented below can be applied similarly to the other methods and will lead to similar conclusions.

In the case of the Blondel-Rey formula, the effective intensity is given by Equation 3:

$$I_{eff} = \frac{\int_{t_1}^{t_2} I(t)dt}{a + (t_2 - t_1)}$$

If we plot $I_{\mathrm{eff}}/I_{\mathrm{max}}$ as a function of pulse duration for a rectangular pulse, we obtain the curve shown in Figure 4. Even for a pulse of several seconds duration, there is a significant difference between the effective intensity and the peak intensity. In other words, there is a significant difference between the effective intensity calculated using Blondel-Rey (or any of the other methods) and that calculated by treating the pulse as a steady light.

If it is decided to treat a flashing light as a steady light if the flash duration is greater than a specified time of less than a few seconds, this will clearly lead to a significant step change in reported intensity. For example, if it is assumed that the steady state intensity can be used instead of the effective intensity for pulse durations of 0.2 s and above, then for a flash of 0.19 s duration the reported intensity will be only about half that for a flash of the same peak intensity but a duration of 0.21 s. Even if the point at which the flash can be treated as a steady light is set to 800 ms, a step change of 20% in the reported intensity will result; the step size is only reduced to 10% if a pulse duration of 2 s is chosen as the transition point. Perceptually, of course, the apparent intensity of the light does not suddenly change depending on whether the duration of the pulse is longer, or shorter, than any specified time period; logically, the minimum pulse duration for which a flashing light can be treated as a steady burning light should be set to a value that avoids a significant change in the calculated intensity.

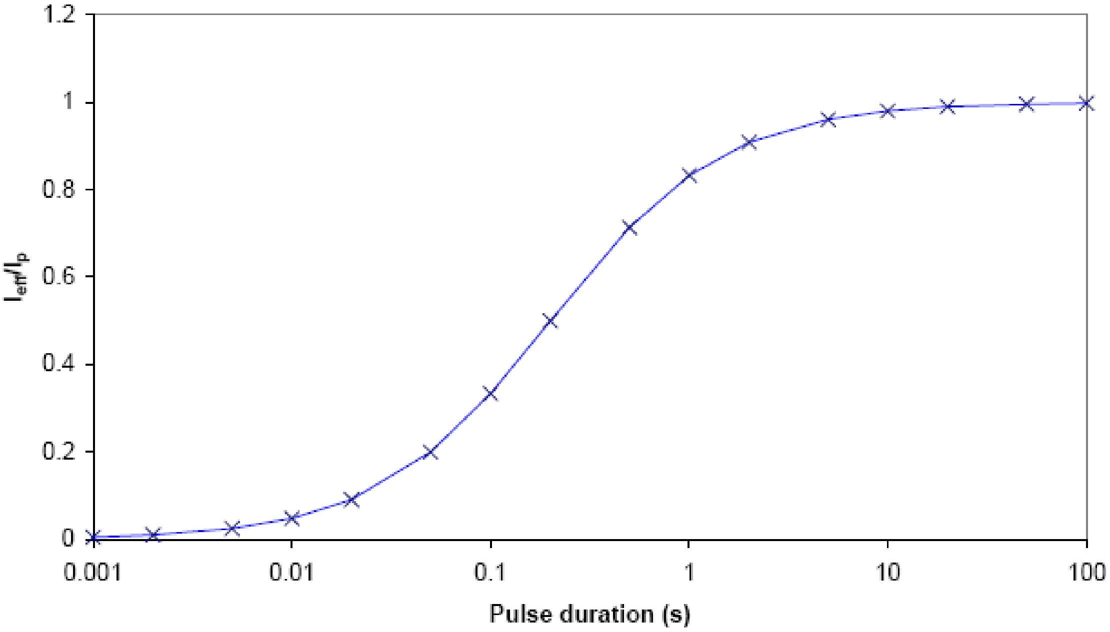


Figure 4. Effective intensity divided by peak intensity as a function of pulse duration for a rectangular pulse.

4.2.2 Effect on Calculated Visual Range

The visual range of a light, whether flashing or not, can be calculated as follows:

$$I = \frac{E_t R^2}{e^{-\sigma R}} \qquad \text{Equation 11}$$

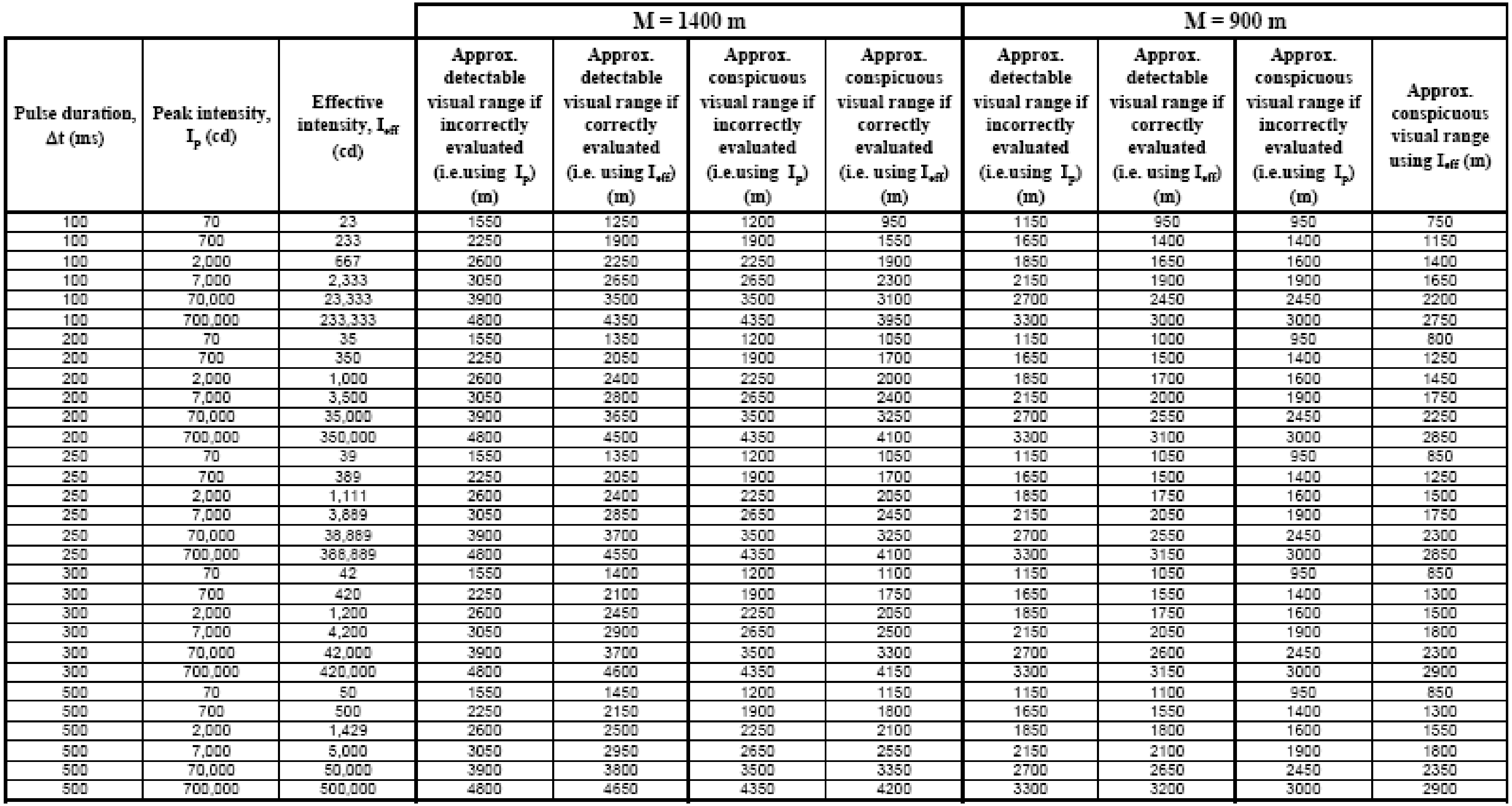
where:

I = (Effective) intensity of the light (candela)
E_t = Eye illumination threshold (lux)
σ = Extinction coefficient (m^{-1})
R = Visual range of a light in the specified conditions of E_t and σ (m)

σ represents the atmospheric attenuation and is given by $\sigma = 2.996/M$, where M is the meteorological visibility in metres.

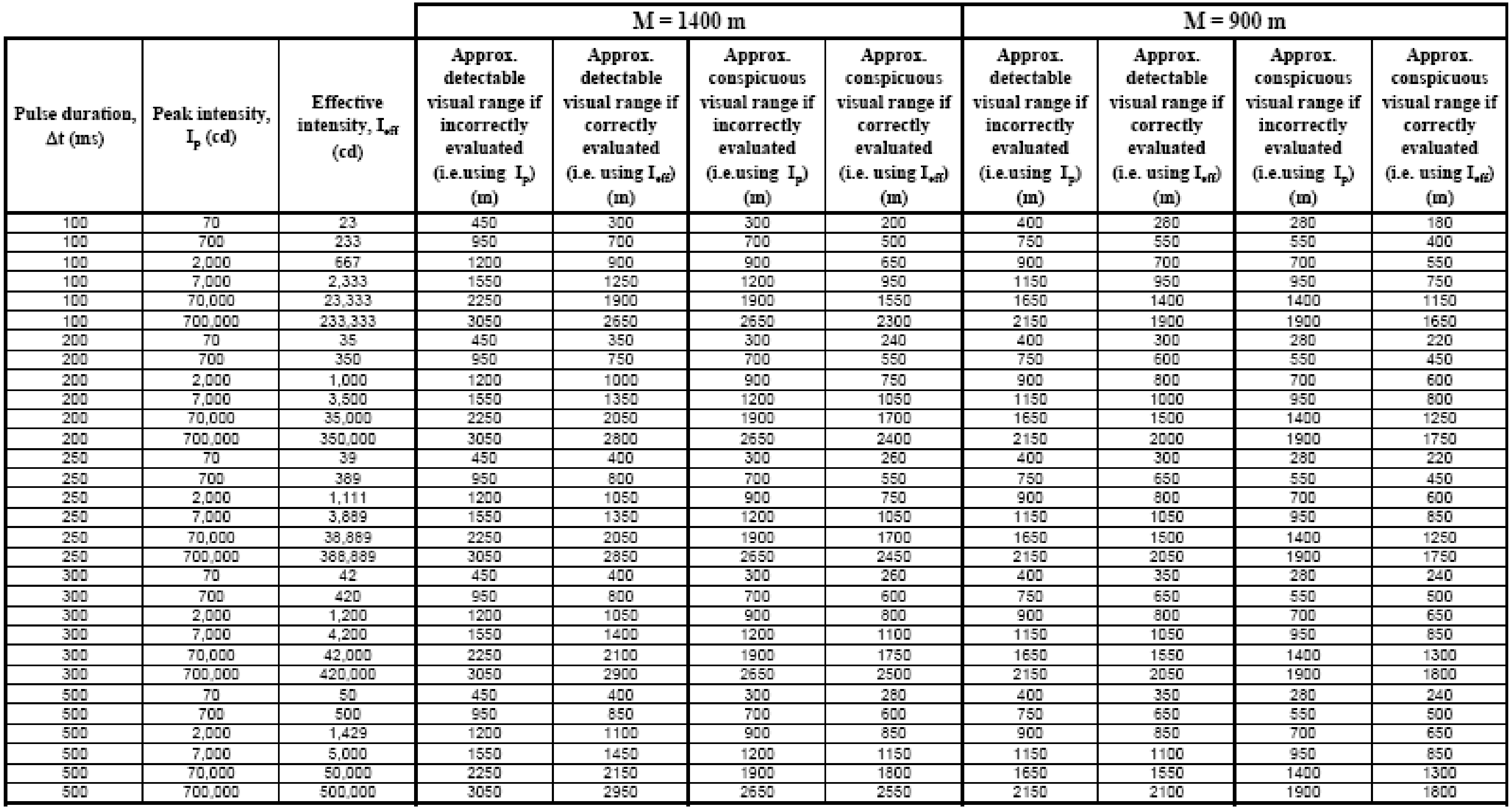
CAA guidelines specify that E_t should be set to $10^{-6.0}$ lux for a typical night and $10^{-4.0}$ lux for a typical day, and calculations are normally performed for $M = 1400$ m and $M = 900$ m ($\sigma = 0.00214$ m^{-1} and $\sigma = 0.00333$ m^{-1} respectively). Furthermore, the CAA states that for a light to be 'conspicuous', rather than just 'detectable', the intensity values should be increased by half an order of magnitude i.e. multiplied by a factor of 3.16. Using these values, the conspicuous visual range can be determined for a flashing light with a rectangular pulse profile for any given duration and peak intensity, and compared with that for a steady burning light of the same peak intensity. The results for a range of nominal pulse durations and peak intensity values are given in Table 5 (night time) and Table 6 (day time) and shown graphically in Figures 5 to 7.

It is also possible to use Equation 11 to calculate the minimum meteorological visibility, M, necessary to ensure that a given rectangular pulse will be detectable or conspicuous under any given set of conditions. Table 7 shows the results of such calculations for flashing lights (rectangular pulse shape) of various peak intensities and pulse durations under typical daylight conditions ($E_t = 10^{-4}$ lux). The variation of M with I_{eff} is also shown graphically in Figure 8.



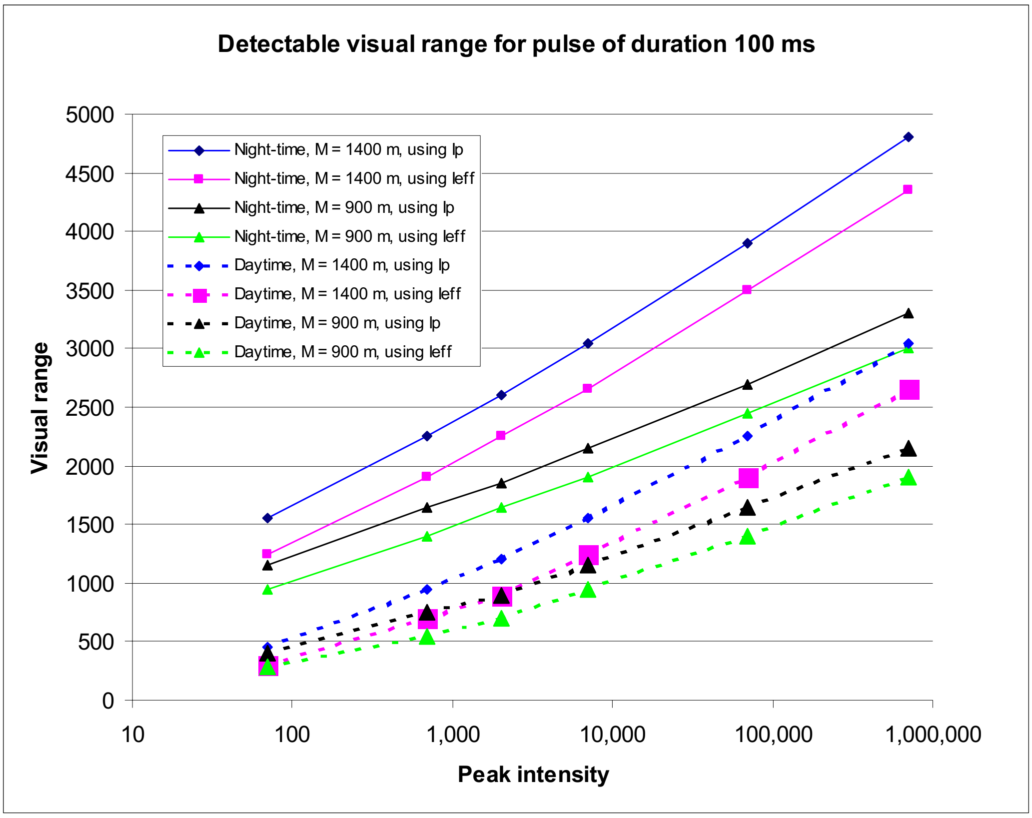
			M = 1400 m				M = 900 m			
Pulse duration, Δt (ms)	Peak intensity, I_p (cd)	Effective intensity, I_{eff} (cd)	Approx. detectable visual range if incorrectly evaluated (i.e.using I_p) (m)	Approx. detectable visual range if correctly evaluated (i.e. using I_{eff}) (m)	Approx. conspicuous visual range if incorrectly evaluated (i.e.using I_p) (m)	Approx. conspicuous visual range if correctly evaluated (i.e. using I_{eff}) (m)	Approx. detectable visual range if incorrectly evaluated (i.e.using I_p) (m)	Approx. detectable visual range if correctly evaluated (i.e. using I_{eff}) (m)	Approx. conspicuous visual range if incorrectly evaluated (i.e.using I_p) (m)	Approx. conspicuous visual range using I_{eff} (m)
100	70	23	1550	1250	1200	950	1150	950	950	750
100	700	233	2250	1900	1900	1550	1650	1400	1400	1150
100	2,000	667	2600	2250	2250	1900	1850	1650	1600	1400
100	7,000	2,333	3050	2650	2650	2300	2150	1900	1900	1650
100	70,000	23,333	3900	3500	3500	3100	2700	2450	2450	2200
100	700,000	233,333	4800	4350	4350	3950	3300	3000	3000	2750
200	70	35	1550	1350	1200	1050	1150	1000	950	800
200	700	350	2250	2050	1900	1700	1650	1500	1400	1250
200	2,000	1,000	2600	2400	2250	2000	1850	1700	1600	1450
200	7,000	3,500	3050	2800	2650	2400	2150	2000	1900	1750
200	70,000	35,000	3900	3650	3500	3250	2700	2550	2450	2250
200	700,000	350,000	4800	4500	4350	4100	3300	3100	3000	2850
250	70	39	1550	1350	1200	1050	1150	1050	950	850
250	700	389	2250	2050	1900	1700	1650	1500	1400	1250
250	2,000	1,111	2600	2400	2250	2050	1850	1750	1600	1500
250	7,000	3,889	3050	2850	2650	2450	2150	2050	1900	1750
250	70,000	38,889	3900	3700	3500	3250	2700	2550	2450	2300
250	700,000	388,889	4800	4550	4350	4100	3300	3150	3000	2850
300	70	42	1550	1400	1200	1100	1150	1050	950	850
300	700	420	2250	2100	1900	1750	1650	1550	1400	1300
300	2,000	1,200	2600	2450	2250	2050	1850	1750	1600	1500
300	7,000	4,200	3050	2900	2650	2500	2150	2050	1900	1800
300	70,000	42,000	3900	3700	3500	3300	2700	2600	2450	2300
300	700,000	420,000	4800	4600	4350	4150	3300	3150	3000	2900
500	70	50	1550	1450	1200	1150	1150	1100	950	850
500	700	500	2250	2150	1900	1800	1650	1550	1400	1300
500	2,000	1,429	2600	2500	2250	2100	1850	1800	1600	1550
500	7,000	5,000	3050	2950	2650	2550	2150	2100	1900	1800
500	70,000	50,000	3900	3800	3500	3350	2700	2650	2450	2350
500	700,000	500,000	4800	4650	4350	4200	3300	3200	3000	2900

Table 5. Detectable and conspicuous ranges for rectangular pulses of different duration and peak intensity values if light is correctly evaluated (i.e. using effective intensity based on Blondel-Rey) and if incorrectly evaluated (i.e. treating pulse as a steady light, using peak intensity values); typical night-time conditions.



			M = 1400 m				M = 900 m			
Pulse duration, Δt (ms)	**Peak intensity, I_p (cd)**	**Effective intensity, I_{eff} (cd)**	**Approx. detectable visual range if incorrectly evaluated (i.e.using I_p) (m)**	**Approx. detectable visual range if correctly evaluated (i.e. using I_{eff}) (m)**	**Approx. conspicuous visual range if incorrectly evaluated (i.e.using I_p) (m)**	**Approx. conspicuous visual range if correctly evaluated (i.e. using I_{eff}) (m)**	**Approx. detectable visual range if incorrectly evaluated (i.e.using I_p) (m)**	**Approx. detectable visual range if correctly evaluated (i.e. using I_{eff}) (m)**	**Approx. conspicuous visual range if incorrectly evaluated (i.e.using I_p) (m)**	**Approx. conspicuous visual range if correctly evaluated (i.e. using I_{eff}) (m)**
100	70	23	450	300	300	200	400	280	280	180
100	700	233	950	700	700	500	750	550	550	400
100	2,000	667	1200	900	900	650	900	700	700	550
100	7,000	2,333	1550	1250	1200	950	1150	950	950	750
100	70,000	23,333	2250	1900	1900	1550	1650	1400	1400	1150
100	700,000	233,333	3050	2650	2650	2300	2150	1900	1900	1650
200	70	35	450	350	300	240	400	300	280	220
200	700	350	950	750	700	550	750	600	550	450
200	2,000	1,000	1200	1000	900	750	900	800	700	600
200	7,000	3,500	1550	1350	1200	1050	1150	1000	950	800
200	70,000	35,000	2250	2050	1900	1700	1650	1500	1400	1250
200	700,000	350,000	3050	2800	2650	2400	2150	2000	1900	1750
250	70	39	450	400	300	260	400	300	280	220
250	700	389	950	800	700	550	750	650	550	450
250	2,000	1,111	1200	1050	900	750	900	800	700	600
250	7,000	3,889	1550	1350	1200	1050	1150	1050	950	850
250	70,000	38,889	2250	2050	1900	1700	1650	1500	1400	1250
250	700,000	388,889	3050	2850	2650	2450	2150	2050	1900	1750
300	70	42	450	400	300	260	400	350	280	240
300	700	420	950	800	700	600	750	650	550	500
300	2,000	1,200	1200	1050	900	800	900	800	700	650
300	7,000	4,200	1550	1400	1200	1100	1150	1050	950	850
300	70,000	42,000	2250	2100	1900	1750	1650	1550	1400	1300
300	700,000	420,000	3050	2900	2650	2500	2150	2050	1900	1800
500	70	50	450	400	300	280	400	350	280	240
500	700	500	950	850	700	600	750	650	550	500
500	2,000	1,429	1200	1100	900	850	900	850	700	650
500	7,000	5,000	1550	1450	1200	1150	1150	1100	950	850
500	70,000	50,000	2250	2150	1900	1800	1650	1550	1400	1300
500	700,000	500,000	3050	2950	2650	2550	2150	2100	1900	1800

Table 6. Detectable and conspicuous ranges for rectangular pulses of different duration and peak intensity values if light is correctly evaluated (i.e. using effective intensity based on Blondel-Rey) and if incorrectly evaluated (i.e. treating pulse as a steady light, using peak intensity values); typical daytime conditions.



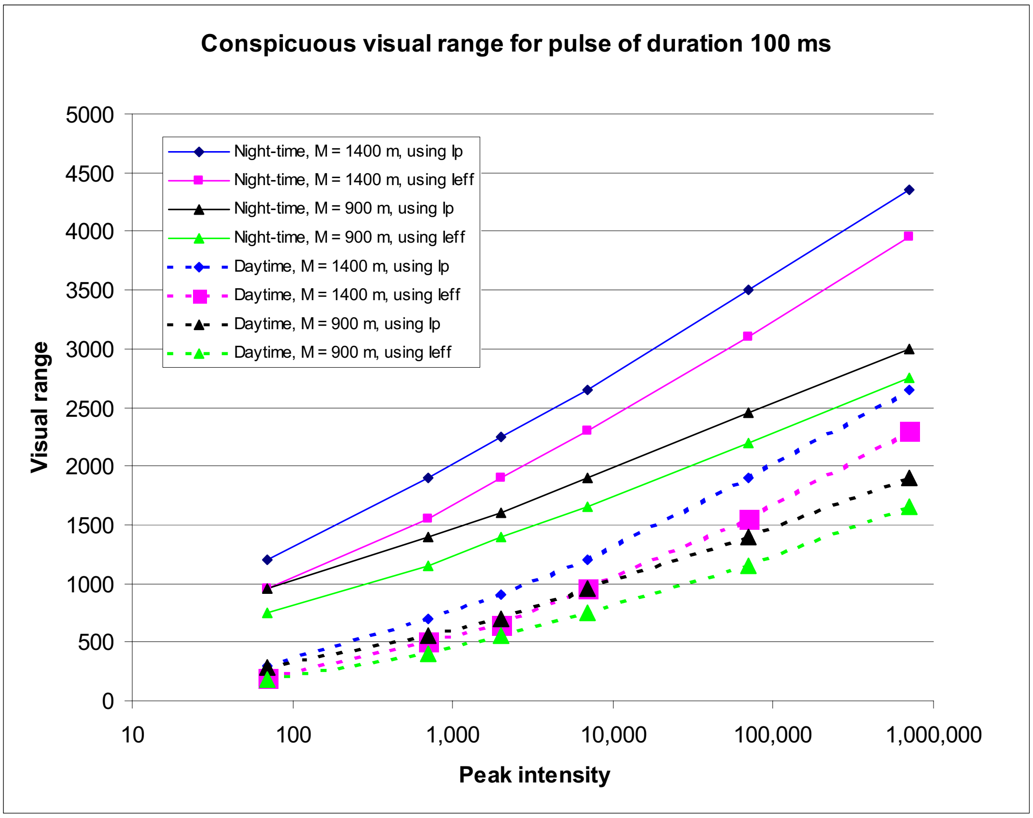


Figure 5. Detectable (top) and conspicuous (bottom) visual ranges as a function of peak intensity for a rectangular pulse of 100 ms duration, depending on whether correctly evaluated (using effective intensity based on Blondel-Rey) and incorrectly evaluated (treating pulse as a steady light, using peak intensity values), under daytime and night-time conditions.

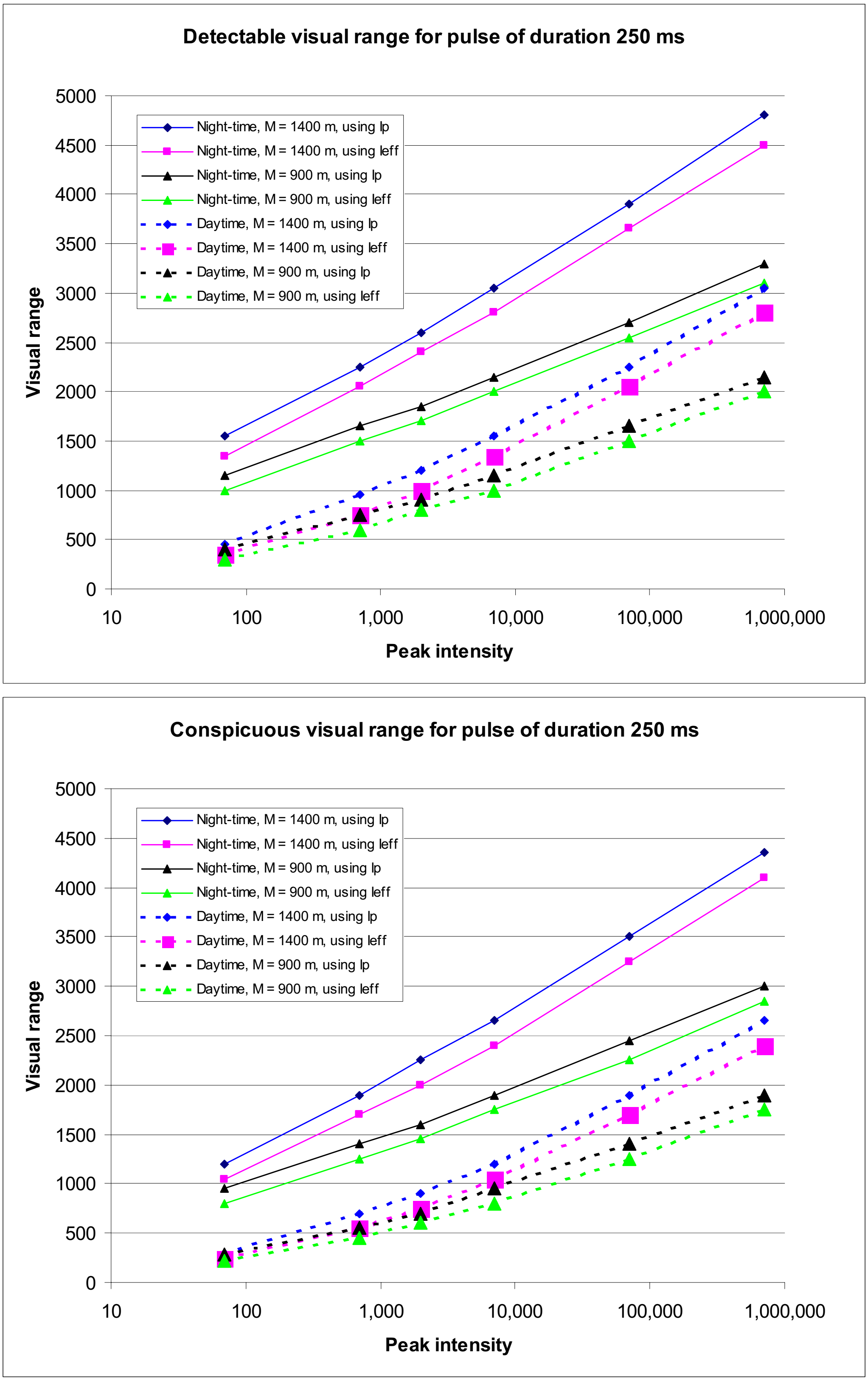
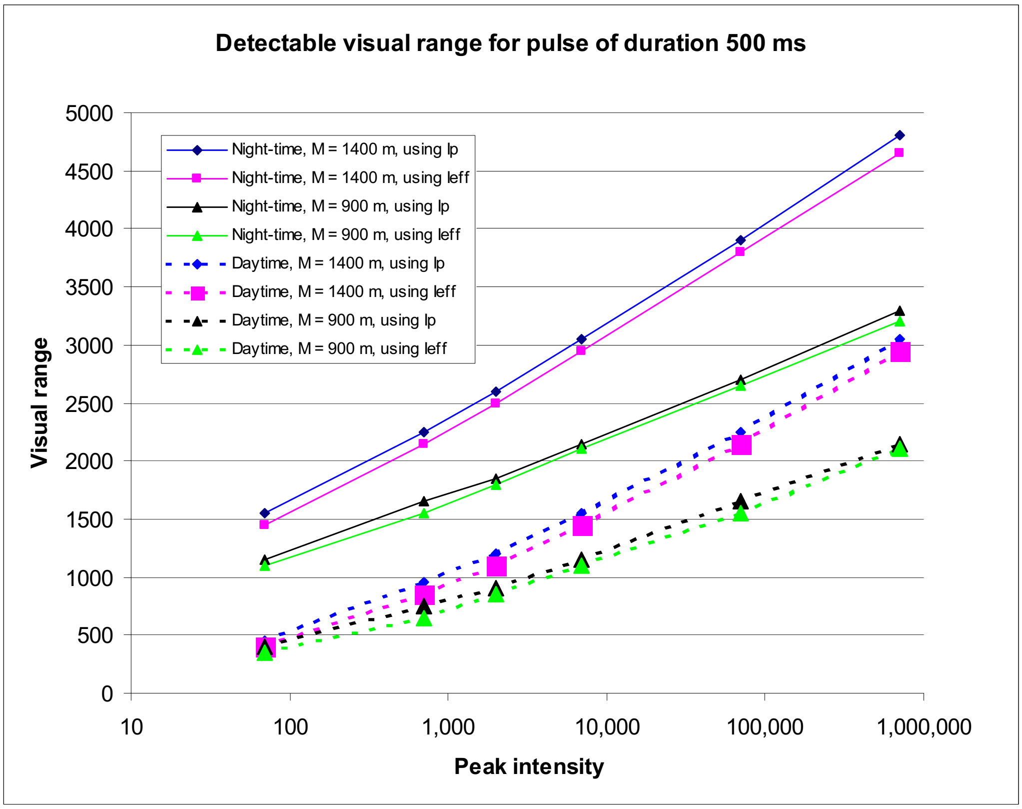


Figure 6. Detectable (top) and conspicuous (bottom) visual ranges as a function of peak intensity for a rectangular pulse of 250 ms duration, depending on whether correctly evaluated (using effective intensity based on Blondel-Rey) and incorrectly evaluated (treating pulse as a steady light, using peak intensity values), under daytime and night-time conditions.



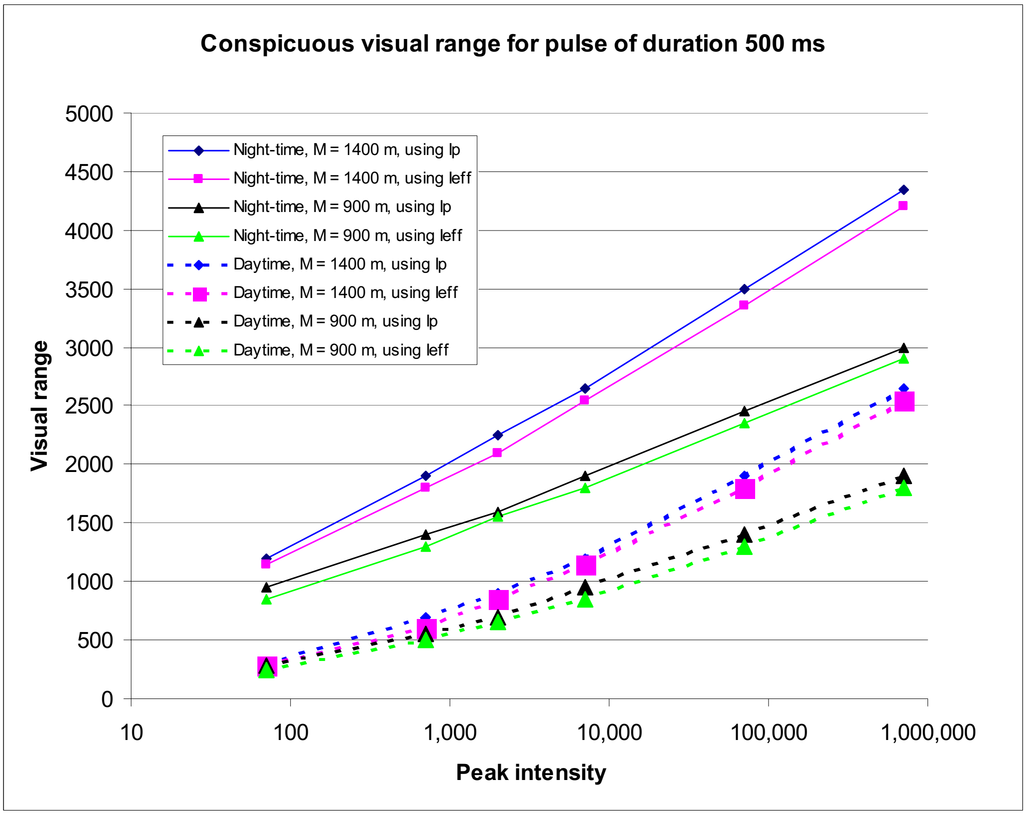
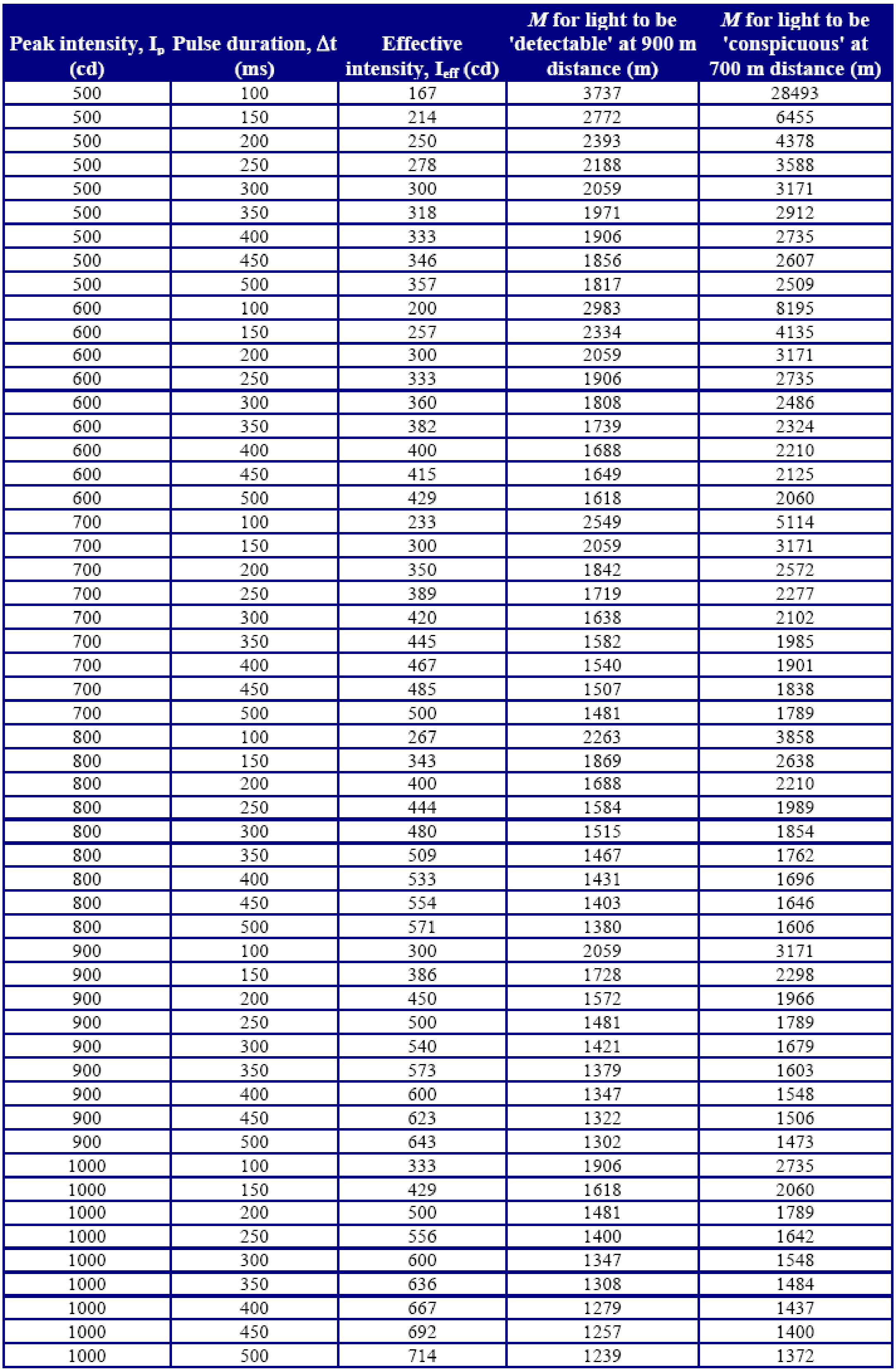


Figure 7. Detectable (top) and conspicuous (bottom) visual ranges as a function of peak intensity for a rectangular pulse of 500 ms duration, depending on whether correctly evaluated (using effective intensity based on Blondel-Rey) and incorrectly evaluated (treating pulse as a steady light, using peak intensity values), under daytime and night-time conditions.



Peak intensity, I_p (cd)	Pulse duration, Δt (ms)	Effective intensity, I_{eff} (cd)	*M* for light to be 'detectable' at 900 m distance (m)	*M* for light to be 'conspicuous' at 700 m distance (m)
500	100	167	3737	28493
500	150	214	2772	6455
500	200	250	2393	4378
500	250	278	2188	3588
500	300	300	2059	3171
500	350	318	1971	2912
500	400	333	1906	2735
500	450	346	1856	2607
500	500	357	1817	2509
600	100	200	2983	8195
600	150	257	2334	4135
600	200	300	2059	3171
600	250	333	1906	2735
600	300	360	1808	2486
600	350	382	1739	2324
600	400	400	1688	2210
600	450	415	1649	2125
600	500	429	1618	2060
700	100	233	2549	5114
700	150	300	2059	3171
700	200	350	1842	2572
700	250	389	1719	2277
700	300	420	1638	2102
700	350	445	1582	1985
700	400	467	1540	1901
700	450	485	1507	1838
700	500	500	1481	1789
800	100	267	2263	3858
800	150	343	1869	2638
800	200	400	1688	2210
800	250	444	1584	1989
800	300	480	1515	1854
800	350	509	1467	1762
800	400	533	1431	1696
800	450	554	1403	1646
800	500	571	1380	1606
900	100	300	2059	3171
900	150	386	1728	2298
900	200	450	1572	1966
900	250	500	1481	1789
900	300	540	1421	1679
900	350	573	1379	1603
900	400	600	1347	1548
900	450	623	1322	1506
900	500	643	1302	1473
1000	100	333	1906	2735
1000	150	429	1618	2060
1000	200	500	1481	1789
1000	250	556	1400	1642
1000	300	600	1347	1548
1000	350	636	1308	1484
1000	400	667	1279	1437
1000	450	692	1257	1400
1000	500	714	1239	1372

Table 7. Minimum meteorological visibilities, *M*, for which flashing lights of various peak intensities and pulse durations will be detectable at a distance of 900 m or conspicuous at a distance of 700 m, in typical daylight conditions where $E_t = 10^{-4}$ lux.

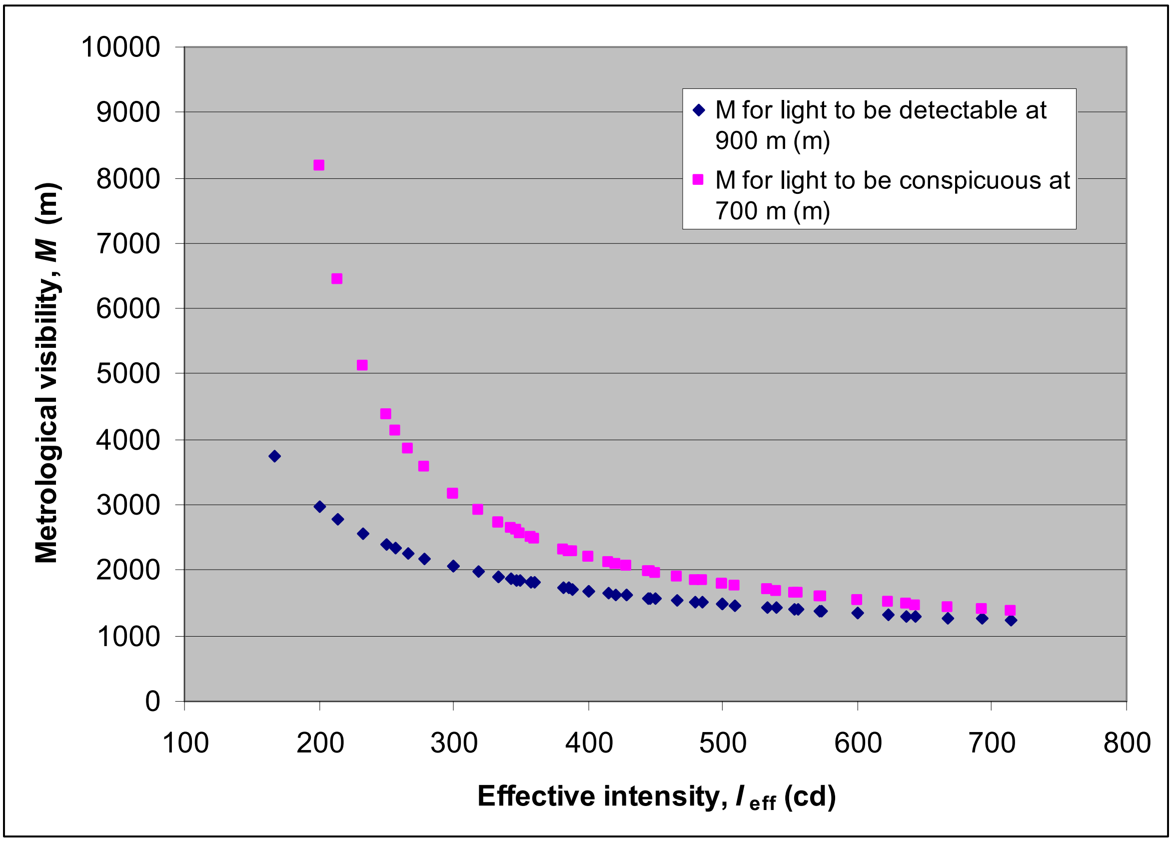


Figure 8. The variation of *M* with I_{eff} in typical daylight conditions, for which a flashing light will be either detectable at a distance of 900 m or conspicuous at a distance of 700 m.

5. CURRENT WORK TO UPDATE RECOMMENDATIONS FOR THE MEASUREMENT OF FLASHING LIGHTS AND CALCULATION OF EFFECTIVE INTENSITY

As indicated previously, the introduction of new lighting technologies (e.g. high pressure discharge lamps and LEDs) into signalling applications is revealing significant discrepancies between the results obtained when using different methods for calculation of the effective intensity of flashing lights. The differences between the methods are considerably less significant when applied to traditional types of flashing light, such as beacons incorporating rotating tungsten reflector lamps. This has stimulated various bodies, most notably the International Commission on Illumination (CIE), to reconsider the recommended methods to be used and the limits of applicability. The CIE is recognised worldwide as the leading authority on light and lighting and its technical guidelines and reports are used as the basis for the majority of national, regional and specific industry sector standards in this field.

CIE Technical Committee 2-49 is charged with preparing recommendations for photometric measurements of flashing lights, including the determination of effective intensity. The recommendations from this TC will be recommended as best practice to other bodies, including the CAA. Work within this TC is therefore of critical importance in the context of this report and will be reviewed here. However it must be remembered that this Committee has not yet completed its work (and is unlikely to do so for at least another 2 years) and therefore the final recommendations may change slightly from those outlined here. Furthermore, it is important to recognise that all of the methods currently available for determination of the effective intensity of a flashing light have been developed and tested using data generated from visibility studies carried out before the introduction of the new types of light source now being developed. Thus they take no account of compounding factors that may influence the apparent conspicuity of a flashing light, such as more saturated colour appearance (common with LEDs). CIE TC2-49 is **not** considering these issues.

Work in CIE TC2-49 has focused on the mathematical robustness of the different methods when applied to pulses with different waveforms. For example, for a robust model the effective intensity for a train of narrow, closely-spaced rectangular ‘flicks’ of light with a mark-space ratio of 1:1, that visually appear as a single flash of width Δt, should be the same as that of a rectangular pulse of the same width and half the peak intensity. It was as a result of such analysis that the modified-Allard method descried earlier was derived, and rigorous testing with a range of actual and theoretical waveforms has so far failed to reveal any situation in which the method breaks down.

In addition to this mathematical approach, TC2-49 has reviewed the experimental data on which the various methods are based and has re-analysed the results of these studies using each of the methods described in Section 3. The most recent study was conducted by the U.S. Coast Guard in 1986 and examined the intensity for threshold detection for flashes comprising of trains of pulses at different intervals and different numbers of pulses. The flash durations ranged from 0.1 s to 0.8 s. In all cases the modified-Allard method gave results in good agreement with the visual perception, thus giving experimental validation for this method (all the other methods showed significant deviations from the measured threshold intensity). Analysis with data from other studies gave similar results.

Other research currently underway that is relevant in the context of this review can be summarised as follows:

- **Ikeda & Nakayama**: addressing areas where the widely accepted Blondel-Rey method may not apply. They have proposed a new model for the perception of flashing lights to account for wavelength dependence and background luminous intensity. Their studies included change in pulse duration (100 μs to 1 s) and based on the results, they did not recommend treating a flashing light as a fixed light under any circumstances.
- **Goodrich on behalf of SAE**: has proposed a method for measuring LED strobe lights, having recognised that deficiencies used in the Blondel-Rey method used in their strobe light testers. Again no recommendation is made to treat a flashing light as a fixed light with regard to pulse duration.

6. INTERIM RECOMMENDATION

As mentioned previously, it is unlikely that CIE TC2-49 will complete its work for at least another two years. However it seems almost certain that the modified-Allard method will be recommended for calculation of the visual effectiveness for all types of waveform, and therefore all types of lighting technology, based on both the mathematical robustness of the method and the fact that it gives results in good agreement with the perceptual response for a range of experimental studies. It therefore seems appropriate that the CAA should use the modified-Allard method on an interim basis, until the report from CIE TC2-49 is finalised. For rectangular flash profiles, this is exactly equivalent to the Blondel-Rey method.

The report from the TC will not recommend a maximum flash duration beyond which a flashing light should be considered as a steady-burning light; choice of a 'cut-off' point in any given application will depend on the magnitude of the step change in calculated effective intensity that is considered acceptable for that application. Since for a rectangular flash waveform the modified-Allard method gives results that are identical to those obtained using the Blondel-Rey method, the analysis presented in Section 4.2 is also applicable to the modified-Allard method. From CAA Paper 2003/06, the maximum permissible duration for a helideck status light is 250 ms. Using either the Blondel-Rey or modified-Allard methods to calculate the effective intensity of a rectangular pulse of light of this maximum duration will give a result equal to just 56% of the peak intensity value. In other words, if a light with a rectangular flash profile and a duration of 250 ms were to be treated as a steady burning light, it would be assigned an 'effective intensity' about 80% higher than that determined using either the Blondel-Rey or modified-Allard methods. This is an unacceptably large difference and therefore it seems appropriate that the CAA should specify that the modified-Allard method should be used for determination of the effective intensity of all helideck status lights, regardless of duration.

In terms of the material in Appendix B of CAA Paper 2003/06, the following amendments should be considered:

- The Blondel-Rey method should be restricted to rectangular flash profiles only. For all other flash profiles the modified-Allard method should be used.
- The reference to a flash duration of 0.15 s in the first sentence of Section 4 of Appendix B should be removed and a statement added to emphasise that the method should be used for all permitted flash durations.
- The measurement methods described in Section 5 of Appendix B should be revised to detail the method for non-rectangular flash profiles (using the modified-Allard method). The simpler Blondel-Rey approach currently described can be retained for rectangular flash profiles only.

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