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ABOUT THE AUSTRALIAN AIRPORTS ASSOCIATION

The Australian Airports Association (AAA) is the national industry voice for airports in Australia. The AAA represents the interests of more than 260 airports and aerodromes Australia wide – from local country community landing strips to major international gateway airports.

There are a further 130 corporate partners representing aviation stakeholders and organisations that provide goods and services to the airport sector. The AAA facilitates co-operation among all member airports and their many and varied partners in Australian aviation, while not contributing to an air transport system that is safe, secure, environmentally responsible and efficient for the benefit of all Australians and visitors.

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The AAA is the leading advocate for appropriate national policy relating to airport activities and operates to ensure regular transport passengers, freight, and the community enjoy the full benefits of a progressive and sustainable airport industry.

These airport practice notes are prepared on behalf of industry to promote ‘best practice’ across Airport operations.

If you have any questions regarding this document please contact the AAA on 02 6230 1110.
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1. INTRODUCTION

Background

The aim of this practice note is to firstly provide a basic overview of Airfield Lighting (AFL) systems. It does not go into depth on technical matters. It is intended as an introduction for people working on airports who have not received specialist training on AFL systems. It is hoped that this document will help people gain a basic knowledge of systems components, how they operate and how they perform so as to assist them to manage a compliant overall facility.

**WARNING:** Untrained personnel should never work on these systems. They can contain high voltage components up to 3,000 V which could kill or maim. Ensure only qualified electrical tradespersons with appropriate specialist AFL training are permitted to carry out this work. Never work on live equipment!

The history of airfield lighting

The development of airfield lighting followed shortly behind the invention of the aircraft.

To compete with other forms of transport and manage emergency needs, night flying eventually became imperative.

Early lighting consisted of whatever was to hand such as beacon fires, either as small markers, or even fuel poured into long trenches. In emergencies auto headlights were sometimes used (and still are, thankfully rarely). The first basic lighting started to appear in the late 1920s and Sydney Airport dates as one of the earliest airports to use lighting. Kerosene flares, also commonly known as Toledo flares, were developed and were popular for a while leading up to and past World War II.

Through the United Nation’s (UN) International Civil Aviation Organisation (ICAO), standards started to be developed from the 1940s. Australia’s Department of Civil Aviation at the time was a frontrunner in developing its own standards and technical solutions. These local efforts contributed to the development of the ICAO standards, and also included some of the world’s first visual approach slope indicator system (VASIS) and later, the T-VASIS system based on symbols, and aircraft nose in guidance (NIG) systems. Since the early 1980s the Australian standards and the ICAO standards have become one and the same in most cases, although differences still occur.

**PLEASE NOTE:** All figures, diagrams and images contained in this Airport Practice Note are strictly for illustrative purposes only. Please refer to the relevant regulations and standards for clarification on specific requirements.

Additionally, the AAA intends to update this Airport Practice Note periodically to reflect changes that occur in regulations and standards. For the most up-to-date version of this document, please visit the AAA website (www.airports.asn.au).
TERMS AND DEFINITIONS

**ABN (Aerodrome Beacon)** is a beacon installed at an airport or aerodrome to indicate its location to aircraft pilots in low visibility conditions.

**AC (alternating current)** is a current which is continually changing its current and direction in a regular fashion such as a mains supply. For instance, for 50 Hz this means the current changes direction 100 times per second, being twice for each cycle.

**AFL (airfield lighting)** also referred to as visual aids provided by aerodrome lighting or **AGL (Aerodrome Ground Lighting)**. Provides visual guidance to pilots for aircraft approaching, departing, and moving around the airfield at aerodromes.

**AFRU (aerodrome frequency response unit)** is radio based equipment that monitors the communication frequency at an airport sometimes referred to as the common traffic aircraft frequency (CTAF). This equipment transmits a recorded message when it monitors a transmission on its frequency. This lets the pilot know that the aircraft radio is working and has selected the correct frequency. After a transmission is received this equipment will only transmit a beep for the next five minutes if another transmission is monitored. Hence this equipment is sometimes referred to as a beep back unit. The AFRU can exist as individual equipment or can be incorporated with a pilot activated airport lighting control (PAALC) into a single unit.

**Airside** is that part of an airport within the secured area reserved for the movement of aircraft and equipment. All persons within this area must have been cleared by security to be there. This may include customs and passport clearance and security clearance for workers.

**ALA (authorised landing area)** is a runway strip that is not certified or registered.

**ALER/VAULT (airport lighting equipment room)** may be a standalone building or part of a building that may house the powerhouse and other operational installations. This building will contain the electrical control equipment to control the various airfield lighting systems. Where control towers are provided the ALER forms the interface between the control tower and the airfield lighting fitting.

**A or Amp (Ampere)** is a unit of measure for the flow of electric charge, commonly referred to as electric current.

**Approach surfaces and take-off climb surfaces** extend from the ends of the runway intended for use for take-off or approach to land. They extend from the end of the runway in the splay left and right of centre line of the runway. These surfaces extend at a much lower gradient than the transitional surface and are dependent on several factors. This gradient is however at around 1:50 and also extends to an elevation of 45 m.

**Apron (ramp)** is the area of an airport where aircraft are parked, unloaded or loaded, refuelled, or boarded. Although the use of the apron is covered by regulations, such as lighting on vehicles, it is typically more accessible to users than the runway or taxiway.

**AsA (Airservices Australia)** usually provides aerodrome and en route and navigational aids and air traffic management services for aircraft within Australia.

**CAS (Civil Aviation Safety Authority)** is the civil aviation regulator for aircraft and aerodromes in Australia.

**CCR (constant current regulator)**

This equipment is essentially a large light dimmer. The capacity of these regulators is typically between 2.5 and 30 kW. The airport lighting regulator is used to control the brightness of the airfield lights. It does this by controlling the current flowing in the cable to the lights. The regulator will typically have between one and seven pre-set levels of brightness. The regulator is usually controlled from the control tower by the air traffic controllers to set the appropriate intensity of the airfield lighting. CCRs rated at higher than 6.5 kVA must be expected to provide output voltages higher than 1000 V high voltage (HV).

**Cd (candela)** is the measurement of the intensity (I) of a light source in a particular direction including the effect of any lens filter. It is independent of distance and is used to describe the intensity of a light source, its brightness and beam spread. In comparing this to water it would be equivalent to pressure or pounds per square inch (psi).
CIE (International Commission on Illumination) is devoted to worldwide cooperation and the exchange of information on all matters relating to the science and art of light and lighting.

C/L (centreline) as in runway centreline or taxiway centreline.

CRI (colour rendering index) sometimes called colour rendition index, is a quantitative measure of the ability of a light source to reveal the colours of various objects faithfully in comparison with an ideal or natural light source.

CT (current transformer) is usually for monitoring/feedback purposes for airfield lighting control equipment. The current flowing in the secondary circuit CT is directly related to the current flowing in the primary circuit of the CT.

CTAF (Common Traffic Advisory Frequency) is required for the mandatory broadcast zone (MBZ).

DC (direct current) is a steady unchanging current provided from power sources such as batteries.

DME (distance measuring equipment) is a transponder-based radio navigation technology that measures slant range distance by timing the propagation delay of very high frequency (VHF) or ultra-high frequency (UHF) radio signals.

Developed in Australia, it was invented by James Gerry Gerrand under the supervision of Edward George 'Taffy' Bowen while employed as Chief of the Division of Radiophysics of the CSIRO. Another engineered version of the system was deployed in the early 1950s operating in the 200 MHz VHF band. This Australian domestic version was referred to by the Federal Department of Civil Aviation as DME(D) or DME Domestic, and the later international version adopted by ICAO as DME(I).

DME is similar to secondary radar, except in reverse. The system was a post-war development of the IFF (identification friend or foe) systems of World War II. To maintain compatibility, DME is functionally identical to the distance measuring component of Tactical air navigation (TACAN). The DME uses a readout in the cockpit of the aircraft of the distance in nautical miles to the beacon. This is generally located at the airfield but can be used as an en route beacon. Once again this beacon will bring the aircraft to the location of the airport but is not suitable for landing guidance in low visibility conditions.

E (Lux) is defined as lumens per square metre and is a measure of the amount of light falling on a surface. Its value is dependent upon the distance from the light source. This is the measurement taken using the light meter/Lux meter. In water terms this would be described as litres per square metre which would equate to the depth of the water.

ERSA (En Route Supplement Australia) is a document that describes each airfield in Australia. It lists all pavements and facilities available at the airport. This includes lighting facilities, standby power and navigational aids. This document is updated four times each year.

Flight strip is the area around the runway contained within the gable markers that is intended for the use of aircraft while landing, taking off and manoeuvring in the air close to the ground. This area must be maintained clear of obstacles or those obstacles must be designed in such a way as to not pose a risk to aircraft.

Genset (generator) is installed to provide backup power in the event of failure of the mains power supply. Where provided as a backup power system, when a mains power failure occurs, the generator will automatically start and assume the system load. It is normal to experience a short power outage while the generator starts.

A genset may also be used as the primary source of power at a location where no mains power is available and is therefore the primary source of electricity. Where generators provide primary power, it is normal to have two or more generators to provide for maintenance and equipment failures.

Glide path indicator produces the vertical information to the aircraft showing its vertical position above or below the design glide path angle on approach to land. The glide path is the electronic equivalent to the visual approach slope indicator system such as the Precision Approach Path Indicator system (PAPI). This equipment is located beside the runway usually close to the point of touchdown.
HIAL (High Intensity Approach Lighting) system is designed to smooth the transition from instrument to visual flight on a precision instrument approach.

Hz (Frequency in Hertz) The repetition rate of an electrical supply being the number of cycles divided by the total time interval. NB 50 Hz is the standard AC power supply in Australia

I (CURRENT) in Amps exists in a closed electrical circuit and is measured in amps. Current flows when there is a potential difference (voltage) between two parts of the closed circuit. This can be likened to the volume of water flowing.

ICAO (International Civil Aviation Organization) Aerodrome Design Manual provides recommendations and advice for the provision of aerodromes. The Aerodrome Design Manual is provided in 6 parts. Parts relevant to AGL are:
- Part 4 Visual Aids;
- Part 5 Electrical Systems; and
- Part 6 Frangibility.

ICAO Annex 14 is provided in two volumes: Volume I - Aerodromes; Volume II - Heliports.

Volume I describes the aerodrome equipment. It is an international standard that is used as the foundation for the Australian standards, although each nation state may make alterations to the international document to better suit their own requirements. The document is often referred to simply as Annex 14.

IES (Illuminating Engineering Society) is a society aiming for the advancement of the art and science of illumination and the dissemination of knowledge to all interested parties.

IWDI/IWI (Illuminated wind direction indicator) or more commonly referred to as a windsock, is designed to swivel to indicate the direction of the wind.

ILS (instrument landing system) is comprised of several beacons (e.g. glide path and localiser) that combine to give precision approach guidance to an aircraft when approaching to land at an aerodrome.

Inner conical surface is the transitional surface and approach take-off on surfaces together form the inner conical surface. This surface is a misshapen cone with the runway at the bottom of the cone and the top of the cone at an elevation of 45 m above the runway.

Inner horizontal surface is a surface at an elevation of 45 m above the runway and starts where it meets the inner conical surface and extends out to a point between 2000 and 4000 m from the runway depending upon the classification of that runway.

Inner marker is an electronic beacon that is located at the threshold and is used for approaches in visibility with decision heights below 60 m. This marker is not generally installed on Australian airports.

kVA (kilovolt-amp) is 1000 volt amps, with a volt being electrical pressure and an amp being electrical current.

kW (kilowatt) is a measure of one thousand watts of electrical power.

Landside is the part of an airport that is occupied by terminal buildings car parks workshops and offices. It is the area that is open to public access.

Localiser produces a radio beam down the centre line of the runway and extends out into the approach to a distance of about 40 km. This beam is used by the instruments in the aircraft to indicate position left and right of the runway centreline. The antenna and equipment of the localiser is located at the end of the runway.

Lm (lumen) is a measurement of the total amount of visible light produced by a light source. It can be likened to the measurement of water in litres.

MA GS (Movement Area Guidance Signs) are designed to assist pilots when they manoeuvre or taxi an aircraft on the airport prior to take-off and after landing.

MBZ (Mandatory Broadcast Zone) encompasses the airspace surrounding a designated, uncontrolled aerodrome, where pilots are required to make certain broadcasts to facilitate mutual separation.

MHz (megahertz) is a unit of frequency equal to one million hertz.

Megger test is a method of testing making use of an insulation resistance meter that will help to verify the condition of electrical insulation.

Middle marker is located at about 1000 m from the threshold. This marker indicates to the pilot that the threshold lights should be visible at any moment and in Category 1 (CAT I) approaches this indicates the position at which the pilot must make the decision to abort the landing and go around if enough visual guidance is not available to complete landing.
MIT (mains isolating transformer) is a large voltage transformer of a typical rating between 1 KVA and up to 10 KVA. It is used on smaller airports to power the airfield lighting circuits. This transformer provides the adjustment of voltage to the airfield lighting circuits to provide the required field current; typically, 6.6 A.

MOS-139 (Manual Of Standards Part 139) is prepared by CASA and is the Australian document that sets out the regulatory requirements for the aerodrome. Lighting standards are primarily covered in Chapter 9.

MOWP (method of works plan) is a document used during major works to detail the process and plan of the works. It will lay out in detail how the work will be conducted and what notifications must be made to ensure the safe operation of the airfield during works, and to provide advance notification of facility and movement area restrictions to aircraft operating at the aerodrome. Also, the way in which materials will be brought on-site will avoid any disruption or safety risk to aircraft.

NBD (non-directional [radio] beacon) is a radio transmitter at a known location, used as an aviation navigational aid. As the name implies, the signal transmitted does not include directional information. The NDB operates at low frequency between 190 kHz and 1750 kHz. The low operating frequency of the NDB signals follow the curvature of the Earth. They can be received at much greater distances at lower altitudes, a major advantage over very high frequency omni directional radio range (VOR). However, NDB signals are also affected more by atmospheric conditions, mountainous terrain, coastal refraction and electrical storms, particularly at long range.

Each NDB is identified by a one, two, or three-letter Morse code callsign. The NDB signal is received by the aircraft and the signal is converted into an indication of direction to the Beacon. The pilot can then follow this direction indication and it will bring the aircraft over the NDB antenna. In this way the beacon can be used to bring the aircraft into the location of the airport. It will not however give guidance for use in low visibility for the approach to land.

NIGS (Nose in Guidance System) for aircraft parking provide visual guidance assistance in maintaining the aircraft on the parking position centreline as the aircraft enters the parking positing. They provide visual guidance to pilots to the aircraft stopping position.

NOTAM (Notice To Airmen) are issued by Air Services Australia to notify pilots of any changes made to an airfield that will change the information listed in the En Route Supplement Australia (ERSA). This document will be raised for changes that will render facilities out of service or require the changing of available pavements.

OBL (Obstruction or Obstacle Lighting) may be required where the Civil Aviation Safety Authority (CASA) has determined that an object or a proposed object has or will intrude into navigable airspace.

OHM is a unit of measurement of the resistance of an electrical circuit. This can be likened to the diameter of a water pipe.

OLS (obstacle limitation surface) also known as the transitional surface, contains a number of conceptual surfaces running upwards and outwards from the runway. They define the limits that any natural or man-made obstacles may extend that could pose a threat to any aircraft in flight manoeuvring in the area of the airport. Anything protruding through these surfaces will need to be considered for removal, marking or lighting to mitigate their threat the movement of aircraft.

Outer horizontal surface is an elevation of 150 m above the runway and extends out to a point around 15,000 m from the runway.

Outer marker is located on the centreline of the approach between 7 to 10 km from the threshold. This marker provides the first fix to the aircraft firming its distance from landing in low visibility.

P (power) in Watts is the rate of transfer of energy measured in watts.

For DC circuits $P = V \times I$
For AC circuits $P = V \times I \times PF$

PAALC (Pilot Activated Airport Lighting Control) is required for a Pilot Activated Lighting (PAL) system. It involves radio-based equipment that receives a coded transmission from the aircraft on the aircraft air band 118mhz-136mhz to turn the airfield lighting on.

The PAALC can exist as a standalone system or can be incorporated with an aeroplane frequency response unit (AFRU) into a single unit on the Mandatory Broadcast Zone (MBZ) or Common Traffic Advisory Frequency (CTAF). Frequency allocations for each individual airport are allocated on application through Airservices Australia.
PAPI (Precision Approach Path Indicator System) is a visual landing guidance system that in recent times has been largely replacing the older 'T' Visual Approach Slope Indicator System (T-VASIS). The PAPI usually comprises four boxes located to the port side of the runway, but can comprise eight boxes; four on each side of the runway. The PAPI provides a colour code signal to indicate where the aircraft is relative to the required approach angle:
» two red and two white signals – ON SLOPE
» three red and one white signal – AIRCRAFT LOW
» four red signals – AIRCRAFT EXTREMELY LOW
» one red and three white signals – AIRCRAFT HIGH
» four white signals – AIRCRAFT VERY HIGH

R/W or RWY (runway) is a defined rectangular area on land prepared for the landing and takeoff of aircraft. Runways may be a man-made surface of asphalt and concrete or a natural surface of gravel or grass.

RGLs (runway guard lights) are designed to help prevent an unintended incursion of an active runway by an aircraft or vehicle. They are sometimes referred to as wig wags.

RVR (runway visual range) is the distance that an aircraft pilot on the runway centreline can view lights along the runway. Usually measured in metres, this can be measured in different weather conditions using a commercial meteorological transmissometers, or manually by counting the number of lights set at a known distance (e.g. runway edge lights).

SCR (silicon controlled rectifier) is an electronic component (semiconductor) that acts like a switch to allow the flow of electrical current when so required. It is sometimes referred to as a thyristor and are frequently used in constant current regulators (CCRs) as the output current control device.

SIT (series isolating transformer) is a small waterproof transformer typically rated between 25 to 300 VA. Its function is to provide electrical isolation between the series field circuit and the lamp circuit. These can be direct buried (although not recommended) alongside the pavement or installed in a suitable pit.

TDZ (touchdown zone) lighting incorporates two rows of lights (barrettes) either side of the runway centreline at 30m intervals extending from the runway threshold for a distance of 900m from the runway threshold.

TWER (tower equipment room) is a room located below the air traffic control tower typically used to interface with electronic and electrical control equipment.

T/W or TWY (taxiway) is a path on an airport connecting runways with aprons/ramps, hangars, terminals and other facilities. They mostly have hard surface such as asphalt or concrete, although smaller airports may use gravel or grass.

Transitional surface is a surface that extends upwards and outwards from the side of the runway at a gradient of 1:7 until it hits an elevation of 45 m above the runway.
T-VASIS (‘T’ visual approach slope indicator system) provides visual indications to pilots to assist them to maintain their aircraft on the correct approach slope as they approach an aerodrome to land. The T-VASIS is gradually being replaced by PAPI systems.

UPS (uninterruptable power supply) usually provides backup power supply to particular equipment when the normal ‘mains’ power supply fails. UPS is commonly provided by electronic equipment utilising batteries as the power source during the period when the normal supply is not available.

V (volt) is the potential difference between two points measured in volts. Voltage can be likened to water pressure.

VOR (very high frequency omnidirectional radio range) is a type of short-range radio navigation system for aircraft, enabling aircraft with a receiving unit to determine their position and stay on course by receiving radio signals transmitted by a network of fixed ground radio beacons. It uses frequencies in the very high frequency (VHF) band from 108 to 117.95 MHz. Developed in the United States beginning in 1937 and deployed by 1946, VOR is the standard air navigational system in the world, used by both commercial and general aviation. By 2000 there were about 3,000 VOR stations around the world. This system has now being gradually being replaced by the use of Global Positioning System (GPS).
2. ILLUMINATION THEORY

2.1 Lighting

Visible light is an electromagnetic radiation the same as heat or radio transmission in the wavelength range of 720 nm to 390 nano-metres.

Red is the longest visible wavelength starting at 390 nm. Violet is the shortest visible wavelength at 720 nm.

The human eye has a non-linear sensitivity to visible light. It is less sensitive at the extremes of the visible range and most sensitive at the centre at 555 nm which is a green light.

**Figure 2.1:** Visible light spectrum

**Figure 2.2:** CIE photopic response curve
2.2 Colour Chromaticity Diagram

This diagram is used to describe the colour of light on a locus plot that describes the colour as a value of X and Y. Airfield lighting light fixtures must produce light with colours within defined limits to meet the requirements of the colours used in the systems.

The airfield lighting colours are defined by limits of the X and Y values and displayed on the diagram below.

Figure 2.3: CIE chromaticity diagram
Figure 2.4: MOS colour boundaries for airfield lighting
Coloured filters

The glass filters used for airfield lighting fitting must be produced to meet strict standards of colour and transmissivity.

Transmissivity is the amount of light that is transmitted through a filter.

Two type of filters are generally used for airfield lighting equipment:
» absorption filters; and
» dichroic filters.

Absorption filters

Absorption filters allow the required light colour to pass through the filter and absorb the light with the other colours. When a lamp such as an airfield lighting tungsten filament globe is used with glass absorption filters, the amount of coloured light that passes through the different colour filters is:
» red 15%
» green 15%
» yellow 35%
» blue 5%

It is clear from the list above that a great deal of energy is lost in the process of producing a coloured light using white light.

Dichroic filters

A technique that has been used to improve the efficiency of colour filters has been to use dichroic filters. The dichroic filter is made up piece of plain glass coated with multiple layers of metallic salts.

These layers work as band pass filters to transmit only specific wavelengths of light. In addition, some of the light passing though the dichroic filter has its frequency changed to the required colour frequency by the dichroic material, meaning more light passes through the filter thus increasing the filter efficiency. In this way dichroic filters can be made with transmissivity levels approximately twice that of coloured glass filters.

Coloured LED lights

The development of sufficiently powerful light-emitting diode (LED) lamps has offered great benefits. The LED produces light of a colour determined by its chemical make-up and therefore does not lose efficiency by use of coloured filters. In addition, the amount of energy required to produce the light is lower than that required for quartz halogen tungsten filament lamps, and the life of LEDs is significantly longer than that of filament lamps (LEDs can last up to 100 times as long as filament lamps).

When used for airfield lighting, LED lights provide lower energy usage, better colour rendition and colour match between the lights, as well as being more efficient. LED lights can provide better service over a longer life period with significantly reduce maintenance requirements. In practice, this could mean over 10 years between replacements.

2.3 MEASUREMENT STANDARDS

Polar diagram

This diagram is used to describe the light output through 360° at a particular angle of elevation.

This is normally produced for omnidirectional lights.

Vertical distribution or XY plot

This diagram describes the light output at various angles of elevation and is commonly used to describe fittings such as low and medium intensity omnidirectional lights.

Isocandela diagram

The isocandela diagram is used to describe the performance of lights such as taxiway centreline lights and high intensity unidirectional lights. This diagram plots points of equal intensity versus angle of elevation and azimuth.
**Figure 2.5:** Polar diagram

**Figure 2.6:** Desired vertical light distribution

**Figure 2.7:** Isocandela diagram
2.4 Types of light sources

A typical quartz halogen lamp will be described by the following terms.

- lamp wattage 100 W
- rated voltage 15.5 V
- lamp current 6.6 A
- lumens 2000 lm
- life 2000 hr

This describes the performance and ratings of a typical airfield lighting and lamp. Changes to applied current will change all the other values.

It can be seen from the below graph that small changes in current will have large effects on light output and life expectancy.

2.5 LED FAQs

Will LEDs really last 100,000 hours?

Yes, in a laboratory, but in real life it will be less and will depend on the maximum 'junction' temperatures of the LED also. The higher the temperature, the shorter the life. So good thermal design of your LED light is absolutely critical.

Are LEDs more efficient than halogen lights?

Yes. Filament lamps typically provide 12-20 Lumen/Watt. New LEDs can provide up to 120 Lumen/Watt which is comparable to the best discharge lights.

Are LEDs cheaper to run?

Yes, both for power and maintenance but this needs to be offset against capital cost considerations.
**Will output remain stable throughout the life of the LED?**

No. There will be some drop offs. This is less for the first 50 per cent of the stated life, accelerating in later years. See manufacturers’ data for the exact losses. Good light fittings will take this into account in their design.

**Will colour remain stable throughout the life of the LED?**

Not 100 per cent, but it is significantly better than previous coloured glass filters. As above, see data sheets. Reputable manufacturers/suppliers will have taken any shifts into consideration in their designs.

**Can I mix filament lamps and LEDs on the same circuit?**

No. CASA will not allow this and for good reason. The main problem is different intensities for a given current. While lamp intensities follow a log curve with respect to current, LEDs have a linear response. Some LED lights have special circuitry to mimic the log curve, however the intensity of LED lights also appear brighter to the human eye. So the lesson is, only change over a complete runway or a taxiway circuit at a time.
3. CATEGORIES OF AIRFIELD LIGHTING SYSTEMS

3.1 Authorised Landing Area (ALA) systems

For ALAs, there are no defined standards.

As for private non-regulated landing strips, it is up to the operator or owner to ensure a safe standard is implemented.

However, it can be said that: "Where there is no specific standard, use the general standard."

This means use the MOS-139. By doing so you can be relatively sure that:

a) you will be providing a safe facility and less likely to be open to fault in the case of an accident or incident, and
b) it will be easier if needed to upgrade and license your airport if so desired at a later date.

3.2 Airfield Lighting (single-stage and three-stage systems) for certified or registered aerodromes

These lighting systems comprise the majority of all AFL installations in Australia, numbering in the hundreds. All airports comprise a runway and a runway strip. It is important that all operators, maintenance staff etc. are aware of relevant parameters for your airport.

These lighting systems are usually either single stage intensity (low intensity runway lighting systems [LIRL]), or three stage intensity systems (medium intensity lighting systems [MIRL]) and in most cases local manual control is supplemented by a PAALC or PAALC/AFRU.

LIRL systems can have the runway edge lights spaced at 90 m apart, MIRL must have their lights spaced at 60 m apart.

CASA notes that with GPS technology, virtually any runway can become an instrument runway. Accordingly, CASA recommends that any new runway edge lights should be spaced at 60 m (required for an instrument runway).

In simple terms, these lighting systems comprise of 6 green threshold lights, 6 red runway end lights, with white edge lights spaced equally at a maximum of 60 metres along the length of the runway. Where runways are 30 metres wide or less, runway lights are spaced laterally at 32 metres, regardless of the pavement width. This is to present a uniform pattern to pilots. For runways that are 45 metres or wider lights are generally placed at 1.8 metres outside the defined runway pavement.

MOS-139 9.10.1(b) below refers to MIRL systems:

b) medium intensity – a 3-stage intensity lighting system suitable for a non-instrument runway or a non-precision approach runway. This is provided to enhance the lighting system particularly in marginal weather conditions. This system cannot be used at an aerodrome that does not have air traffic services or similar personnel.

NOTE: This requirement is for controlling light intensity during the landing phase. This section is not to be confused with lighting systems controlled by a photo-electric cell which can provide day, twilight and night intensity settings based on ambient conditions.

At an aerodrome with an air traffic service (ATS), the runway lighting systems must be equipped with an intensity control so that the ATS can select light output to suit ambient conditions and avoid dazzling pilots. These airports are normally provided with medium intensity runway lighting systems.

Medium intensity runway lighting systems can be provided at other aerodromes where air traffic control (ATC) is not provided, however these aerodromes must have specific personnel who are trained and authorised to select the required runway light intensity. In MOS-139 Clause 9.1.14.2, CASA requires that at these aerodromes a Certified Air-Ground Radio Operator (CAGRO), a Unicom operator, or similar authorised and responsible person with two-way radio communications with the aircraft must be available to provide the aerodrome lighting intensity control.
Three-stage systems triggered by a PAALC utilising the settings DAY/TWILIGHT and DARK are acceptable under MOS-139 and are not to be confused with ATC controlled systems. In these cases, the PAPI is provided with three intensity controls and the runway lighting is usually provided with single intensity (which is selected for TWILIGHT and DARK conditions).

Intensity ratios between the various components of the lighting systems are important and should be consistent through all airfield lighting systems. If runway edge lighting is considered 1.0, then threshold lights must be 1 to 1.5 the intensity of the runway edge lights' intensity. Runway end lights must be 0.25 to 0.5 the intensity of the runway edge light intensity.

Taxiway lights used in a simple regular public transport (RPT) airport are normally blue elevated edge lights, with yellow holding point lights placed where the flight strip intersects the taxiway. In some cases, inset centreline taxiway lights are used and these are green bidirectional so that guidance is assured in both directions.

An integral and necessary part of this system is a fully illuminated wind direction indicator which is clearly visible from all approaches. In some cases it may be necessary to have more than one (see Chapter 13), but generally speaking one is sufficient for shorter runway lengths. You need to be mindful of the 1:7 obstacle limitation surface (OLS), also sometimes referred to as the transitional surface, and with wind indicators normally 8 metres in height so they need to be placed a minimum of 56 metres outside the runway strip so as not to infringe.

Apron floodlighting is also required under MOS-139 standards to ensure the safety and security of passengers and aircraft. All details for apron floodlighting requirements, lighting levels and uniformity levels are covered in MOS-139 Section 9.16. Aircraft must be lit from both sides and this can require multiple poles and lights. Most major lighting companies will perform a computer design as part of their service. It is important to note that all lighting provided on the aprons must limit light above the horizontal and be low glare.

PAPI systems are normally required to be installed at airports that have regular jet RPT flights or 'black hole approaches' as deemed by CASA. PAPI systems operate on three stages and are activated regardless of ambient light conditions. (i.e. they are activated DAYLIGHT/ TWILIGHT and DARK settings). Chapter 10 of this document covers PAPIs and PAPI installation in more detail and the relevant standard is MOS-139 9.9.4.

Obstacle lighting and beacons may be required and are covered in Chapter 14 of this document. Please also refer MOS-139 9.4 for obstacle lighting and MOS-139 9.5 for aerodrome beacons

3.3 CAT I/II/III airfield lighting overview

It is not the intention of this practice note to cover this area in depth as these are mostly confined to larger airports with their own AFL professionals and designers. However as an overview:

CAT I – compromises of high intensity six-stage runway lighting and corresponding high intensity approach lighting (HIAL) systems. More often than not taxiway lighting is three-stage inset centreline, due to the added complexity of taxiway systems. This is to avoid the 'sea of blue' effect that can occur where multiple taxiways are lit using blue elevated lights that can be seen from all directions. Illuminated wind indicator (IWI), PAPI, apron lighting etc. are also used similar to RPT airports. Additionally, movement area guidance signs (MAGS) start to be used, again due to the complexity of taxiways, holding points and mandatory stop bars, see MOS-139 Section 8.6). Runway guard lights are a MOS requirement (See MOS-139 Section 9.3.16)

It is also requirement for CAT I systems to have a backup power supply capable of activating within 15 seconds of mains failure. This is achieved with appropriate diesel backup genset

CAT II – These are similar to CAT I systems with the addition of red barrettes in the approach lighting system, runway centreline lights and touchdown zone lights.
Figure 3.1: CAT I 'Calvert' approach light pattern

Figure 3.2: CAT II and III approach light examples
In the case of a mains failure the backup power supply must be able to switch over within a maximum of one second. It can be expensive to achieve this via a static (battery) UPS or a rotary no-break system. In practice some airports achieve this standard by running off their back up generators in low visibility conditions (i.e. the genset becomes the primary supply). The usual primary (mains) then becomes the backup supply which can be easily switched in the one second required. Serviceability of a CAT II system must be 99.9%.

**CAT III** – Runway lighting requirements are physically identical to CAT II with the main difference being taxiway routing. i.e. the spacing between taxiway centreline lights can be reduced down to 7.5m

Also note serviceability/availability standards which in this case must be 99.99 per cent of the time.
4. SERIES CIRCUITS

4.1 The theory of operation

One of the primary objectives of the airfield lighting is to produce light signals of even and consistent brightness regardless of where the light fittings are located on the field or their distance from the source of supply of power.

To achieve this, it is necessary to use a cabling system that is simple in nature and will deliver power reliably to the light and maintain power to all other fittings without changing brightness even after the failure of other lights in the system.

Up until recently the main type of lamp use for airfield lighting has been the tungsten filament lamp. These lamps generate light when current is passed through the lamp filament, heating the filament and resulting in the production of light. The amount of current that passes through the lamp filament is generally proportional to the voltage applied across the filament.

LED lights are now coming into use around airfields and this is starting to change how designers work to improve efficiency, through life reliability and costs.

4.2 Parallel circuits

The most common type of cabling system used to power lights in buildings and auto electrical systems is the parallel wiring system. This system uses a ‘constant’ voltage with two wires; one wire running to all the lights in the circuit and the other wire returning from the lights to source of power.

This system of cabling is the most simple and convenient, as it requires only a constant voltage which is available from the AC mains or a DC battery supply.

With this system, the failure of one lamp will not necessarily affect the operation of the other lamps in the system. In buildings and automotive use, the source of power and the lamp that it drives are generally only a few metres apart and rarely exceeding several hundred metres. Even so, if the cable run becomes long or the number of lights in the circuit is increased, voltage loss (voltage drop) in the cabling becomes a serious consideration.

Those lights located close to the source of supply will be at full brightness, however as the distance of the source of supply increases the resistance of the cable (causing voltage drop) will reduce the brightness of the lights.

Figure 4.1: A simple series circuit
A tungsten filament lamp will be significantly reduced in brightness with only a small per cent reduction in applied voltage because the light output versus the supply voltage is not linear.

The large area of airports necessitates the use of very long electrical circuits to provide power to all parts of the runway and taxiway lighting systems. The distances involved are routinely in excess of 4 km and may exceed 10 km. The number of lights on a circuit is also often very large and may be around 200 lamps in a large circuit.

To provide power to the circuits, and to ensure the minimum ‘voltage drop’ around the lighting systems, using conventional parallel wiring would necessitate the use of extremely large cables that would be very expensive to source and install.

### 4.3 Series circuits

The alternative to a parallel system is to connect the lights in series. In these systems the connections are made from the power supply to the first light, then from that light each successive light in turn, as a series loop, with the last light then connected back to the source of supply.

In this configuration electrical power sourced from the supply must flow through each lamp in turn and each lamp will experience the same amount of current flowing through it and therefore each light around the system will be of even brightness regardless of its distance from the source of supply. These systems are generally called series current systems.

With series current systems the voltage of the supply source will need to be of sufficient value to cause the required current to flow in the circuit.

In simple terms this means that if each light requires 10 V to operate and there are 100 lamps in the circuit the voltage needed to power the circuit would be one thousand volts (1000 V). This arrangement has a number of obvious difficulties.

Firstly, the failure of one lamp will break the circuit and cause all lamps to fail (think of Christmas tree lights) and this is obviously a serious problem in a circuit used to provide guidance to an aircraft on approach to land where reliability is the highest priority.

Secondly, the voltage required to power a large circuit is very high and this is a serious danger to anyone working on this equipment, and the equipment must be designed to operate at the highest voltage that the equipment could be expected to operate.

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**Figure 4.2:** A simple parallel circuit
During World War II a number of airfield systems were brought into Australia that used this simple series connection with the addition of the small cut out device that short circuited to re-establish the connection in the event of the failure of the lamp. This equipment had each light fitting manufactured in such a way as to be able to operate at the full system voltage of several hundred volts. It was very dangerous and posed a threat to life from contact with the equipment while operating at any time.

A safer and more suitable alternative was required and the use of the series isolating current transformer was adopted to provide electrical isolation from the main ‘primary’ circuit and to provide a reduced voltage on the secondary circuit connecting to the lamp. In this way the voltage supplied to the light fitting is relatively low.

Series isolating current transformers are generally known as SITs. The particular advantage of the SITs is that if the lamp filament fails (goes open circuit) the current in the SIT primary circuit continues to flow so that all the other lights connected to the circuit stay on.

This has become the universally accepted method of powering airfield lighting throughout the world.

In the past it was common to work on the light while power was applied. This practice was somewhat safer when the circuit sizes and the wattage of fittings was relatively small and the power was from a sinusoidal source. This practice relied on the integrity of the insulation/isolation of the series isolating transformer. However, this practice is no longer deemed safe in today’s workplace health and safety environment, and equipment should be de-energised prior to commencing work.

Depending upon the complexity of the airport, the airfield lighting circuits can be as simple as one single loop of cable for the runway and taxiway of a small country airport, or involve dozens of circuits controlling multiple facilities for large international airports.

The installation of the cable in the ground can be direct buried or in cable ducts and conduits.

Most systems installed in Australia prior to 1990 were direct buried. Today this needs an approved document path to show how compliance can be met. Now the practice of using cable ducts or conduits has become the most common standard system of installation, and this is strongly recommended and preferred. Whether direct buried or in ducts the cables follow marked defined routes from the ALER to the equipment they power.

Airfield lighting circuits are routinely operating at voltages above 1000 V. This would normally constitute a high-voltage circuit requiring special treatment with the cables buried below 750 mm.

The installation of lighting cable within the airside of the airfield was previously covered by a special dispensation (refer To MOS Part 139 Clause 9.22.1). However, the dispensation has now lapsed and compliance with AS/NZS 3000 is now required. It is recommended that a suitably qualified professional person such as an AFL consultant be employed to provide advice on the available options for the airfield lighting cabling systems. Refer to the related case study in Chapter 21 for further guidance.

The layout and size of the airfield necessitates the installation of the airfield lighting cable to run for considerable distances in close proximity to the cables of other airfield lighting circuits. The combination of high voltage and close proximity to other circuits means that the cables can act like transformers and the electromagnetic field around the cable can induce high voltages into other cables, even when they are off.

NOTE: Great care must be taken when conducting work on any primary airfield lighting circuits to ensure that the circuit cannot be energised directly or become energised due to induced voltages.
4.4 Maintenance

The maintenance on series circuits is mainly a case of watch and act for low impedance (low insulation resistance) to earth. It is recommended that regular (at least annually and preferably more frequently) inspection tests are carried out. This requires a qualified electrical tradesman to carry out the impedance (insulation) test to earth, usually employing a suitable tester such as a ‘megger’.

The circuit must be disconnected and isolated from the mains power while this is done i.e. the system must be ‘out of service’. Ensure you have clearance to do this.

These cable insulation resistance readings should be recorded and kept in a place known by the responsible maintenance staff. By keeping these records, the trend can be observed, and action taken when necessary, to improve the circuit condition.

A new installation should have a current impedance at least over 100 M ohms, preferably 1G ohm. It is strongly recommended that insulation resistance of at least 1G ohm be required on completion of new works and that this be maintained by the contractor during the defect liability period to ensure suitable ongoing service of the cabling system after the end of the defect liability period.

A circuit reading below 1M ohm should be monitored closely and appropriate action put into place to rectify the low insulation resistance problem. Where the insulation resistance of the cabling system has fallen below 100K ohm the system should be repaired immediately.

4.5 Troubleshooting

WARNING: Due to the potential for high voltages, this work should only be carried out by qualified electrical staff.

When a circuit has failed, or the circuit impedance to earth is very low, remedial action is needed. The first step usually involves a drive around the cable route looking for the obvious e.g. earth works such as trenching, obvious lightning strike damage such as missing pit lids etc. If this does not locate the damage, then the slower option comes into play.

This involves isolating the circuit as per the insulation tests described in the maintenance section, then cutting the circuit around the mid point of the cable. If cable connectors are used, typically it is possible to open the circuit without cutting the cable. Normally you would start at the half way point (i.e. the far threshold). Then insulation test each half of the circuit to determine which half contains the fault. Continue this process until the faulty segment is isolated and repairs can be performed.

Note the most common faults to be expected are:

» lightning strikes;
» earth works;
» slow decline in earth resistance;
» bad connection; and
» failed SITs.
5 TRANSFORMERS AND CONSTANT CURRENT REGULATORS

5.1 Series isolating transformers

Airfield lighting systems generally use series current circuits.

Current transformers are special transformers utilised to reflect the current in the primary (main) circuit into the secondary (output) circuit.

Series isolating current transformers (SITs) used in airfield lighting systems provide electrical isolation from the primary circuit to the low voltage secondary circuit to power the lamp. In this way the voltage supplied to the light fitting is relatively low, typically in the range of 6 to 30 V (although this can be as high as 150 V depending on the light type).

The primary winding of the SITs are connected as a series connection. The secondary of each SIT is connected to the lamp of the light fittings. In this way electrical isolation is achieved from the high voltage primary to the relatively low voltage secondary winding powering a lamp.

As current flows on the SIT primary circuit it magnetises the core of each transformer. This magnetic flux induces a voltage in the secondary of the transformer and the resultant current flows through the lamp.

When a lamp fails, the current flowing in the secondary of that SIT falls to 0 ampere (0A) and this constitutes a very high secondary impedance. In a conventional current transformer this high secondary impedance would be reflected into the primary by the turns ratio of the SIT.

Most airfield lighting SITs have a turns ratio of around 1 to 1. Even so, the infinite impedance of the secondary would be reflected as an infinite impedance into the primary winding.

Figure 5.1: Series circuit layout
The result of this would be to effectively open circuit the primary and cause the primary current to fall to 0A. This of course would be a significant disadvantage similar to the simple series connected circuit.

To stop this happening the airfield lighting current transformer (the SIT) is designed with only sufficient iron in the magnetic core to supply the flux necessary to drive the lamp.

When the lamp open circuits and the current in the secondary falls to zero the amp turns of the secondary also fall to 0A and the ‘amp turns’ of the secondary no longer oppose the flux generated by the primary.

The flux in the core therefore rises however with only a limited amount of iron the flux cannot rise significantly and therefore the iron core quickly becomes saturated. When saturated the SIT is now no longer an inductive device and the current is only limited by the resistance of the copper winding.

The overall impedance of the SIT when unloaded (that is the lamp has failed) is somewhat higher than when unloaded, usually around two times. The voltage present at the secondary terminals is also higher, generally around twice the on-load root mean square (RMS) voltage.

Ultimately what this means that the SIT is unloaded when the lamp filament is working normally and fully loaded when the lamp filament has failed (which is contrary to what you would normally expect). When the lamp filament has failed, the SIT presents a higher load on to the power supply system.

Airfield lighting circuits are frequently powered by phase-controlled regulators and the output of this equipment is non-sinusoidal. The result of this distorted wave form can result the peak voltages being considerably higher than the RMS level. High wattage SITs of 200 and 300 W can generate open circuit voltages in the range more than 200 V peak.

In summary the SITs and lamp circuit arrangement achieve an even and consistent lighting output from all lights in the circuit regardless of the length of the circuit. SIT gives isolation from the dangerous primary voltage. The relatively low voltage at the light fitting allows for a more compact construction and safer environment.

5.2 Mains isolating transformers

Airfield lighting circuits generally utilise a series connection arrangement. This means that the voltage supplied to the circuit will have to vary depending on the length of cable and the number of lights connected to it.

Both of these parameters are widely variable and so supply to the lights has to be capable of adjustment over a wide range, and potentially high voltage.

The international standard for power supply for airfield lighting circuits has a maximum current of 6.6 A. It therefore follows that the voltage required to pass 6.6 A through a 1 kW load will be:

\[
V = \frac{W}{I}
\]

\[
V = \frac{1000}{6.6} = 151.5 \text{ volts/KW}
\]

Airfield lighting circuits can vary between 1 kW and 30 kW therefore the system voltage will vary from 151 V to 4,545 V.

The mains power supply in Australia is fixed at either 240 V phase to neutral or 415 V phase to phase. It is clear that these two voltage sources cannot supply the range of airfield lighting loads. To modify the voltage required to supply the airfield lighting a voltage transformer is utilised to adjust the voltage to the required level.

A mains isolating transformer (MIT) is a simple power transformer. It has a primary winding suitable to connect to the mains supply of 240 or 415 V.

The secondary winding will have a voltage suitable to supply the airfield circuit. As the airfield lighting field circuit load increases so the voltage must be increased to match the power rating of the transformer. To make this equipment more flexible so that it can be adjusted on-site to match the load, these transformers are provided with a number of secondary tappings to allow adjustment of the output voltage to match that required for a specific circuit. These transformers may also have a large range of tappings so that they can also be adjusted to supply multiple intensity stages.

MITs also usually have a range of tappings on the primary so that the transformer input can be adjusted to match the local voltage levels.
The mains isolating transformer as its name suggests, also provides isolation between the primary and secondary supplies to the lighting.

The mains supply is arranged with a reference to earth. However, the secondary has no such earth connection and is operated independent of earth. This has the advantage of making the airfield lighting circuit more tolerant of ‘earth leakage’ and in fact airfield lighting circuits can operate satisfactorily with very low earth impedance.

It also follows that with no earth connection on the secondary of the transformer there can be no large earth fault current and so an earth fault on the secondary will not cause fault current flow in the primary winding. This does not mean that contact with the secondary circuit will not cause electrocution as some magnetising current will flow to ground sufficient to cause fatal electrocution.

**Advantages**

1. The MIT is a simple rugged reliable device that is not easily damaged by lightning surges.
2. The MIT is relatively inexpensive compared with the alternative series current regulators.
3. The intensity of the airfield lighting can be controlled using tap changing relays.
4. It is more compact than the equivalent regulator.
5. The load power factor is relatively stable for different fixed loads.

**Disadvantages.**

1. The MIT cannot be used on circuits that have varying loads such as taxiway segment selection.
2. Intensity changing on high-power circuits in excess of 10 kW requires switching high voltages that require special switching circuitry.
3. A short circuit or partial short circuit on the airfield lighting circuit can cause very large and destructive fault current to flow.
4. Changes in supply voltage will cause variations in the airfield lighting circuit current which will cause a similar change of intensity of the lights.
5. Changes in the load such as the loss of a number of lamps will also cause a change in the series current. The open circuit lamp will reflect a higher impedance into the circuit which will result in reduced circuit current.
6. The tapping of the transformer windings cannot produce infinitely variable adjustment of current. The tappings can only be selected to obtain currents close to the desired level.
5.3 Constant current regulators

Regulators are routinely used to control all forms of energy. This includes air, hydraulics and electricity. All regulators have a common function which is that they control the amount of energy they are designed to regulate.

The regulator may control air pressure, or water or oil pressure and flow. Electrical regulators control voltage or current.

Voltage is of course electrical pressure, and current the electrical flow. All regulators have one thing in common: they compare the value of the unit they are controlling against the value of the level of the unit that is desired to be achieved. The regulator is then able to adjust the supply to achieve the required output.

An air pressure regulator will commonly use spring tension to set a level of poundage and control a valve to regulate the pressure in the supply line. Similarly, a voltage regulator will use a preset voltage as a set point to control a regulating circuit to maintain a constant voltage output.

The series current regulator as its name implies uses an electronic circuit to control the amount of electric current flowing in the output circuit. This requires a machine that can control the amount of electrical energy flowing into the circuit, a feedback circuit that will measure the amount of current being achieved, a comparing circuit that will compare the amount of current flowing to the amount that is required (the set point) and adjust the output of the circuit with a power control device to maintain the desired current.

5.4 Silicon controlled rectifier

The silicon controlled rectifier (SCR) or thyristor is the device that is most commonly used to control the flow of electricity through the regulator. The SCR is a solid-state rectifier similar to a diode.

The diode is in effect an electric one-way valve. It will allow current flow in one direction. When the polarity of the voltage applied to a diode is such that the diode is forward biased, it will conduct the electricity until the voltage is removed or reversed which will cause the diode to be reversed biased and it will block reverse current flow.

The diode is a two-layer silicon device and the SCR differs in that it is a four-layer device.
The SCR has another terminal which is called the trigger or gate. The characteristic of the SCR is that when it is forward biased (the condition that would bring a diode into conduction) it will not conduct until a small electrical signal is applied to the gate connection. When this signal occurs the SCR will begin conducting if it is forward biased and will remain in conduction until the electric current falls to 0 or it becomes reversed biased.

In Figure 5.5 it can be seen that with an AC wave form applied to the circuit the SCR will not conduct until a trigger potential is applied to the gate. Once triggered, the SCR begins conducting and will continue to conduct even if the gate pulse is removed.

In this way it can be seen that the amount of power flowing through the load ‘RL’ can be controlled by controlling how long the SCR is in conduction and therefore how much applied power is allowed to flow through the load. The earlier in the half cycle that the SCR is brought into conduction (triggered) the more power will be applied to the load.

If triggering the SCR is delayed until later in the cycle the amount of power will be reduced. The circuit above is only controlling one half of the wave and in the other half no power can flow because the SCR, like the diode, will not conduct when reversed biased.

To control the power flowing into the output transformer that is connected to an airfield lighting circuit it is necessary to control both positive and negative half cycles of the power wave form. To do this it is necessary to use two SCRs arranged in a back-to-back (anti-phase connection).

Figure 5.5 describes this connection and shows how the two SCRs control both halves of the AC wave.

Figure 5.6 shows an applied AC wave with one SCR ‘Th1’ controlling the positive half of wave form and the other SCR ‘Th2’ controlling the negative half. This is the basic power control system used in the airfield lighting, constant current regulator.
**Basic regulator circuit**

The circuit in Figure 5.7 describes the major components of the series constant current regulator (CCR). Over time there has been various systems of achieving constant current regulation. However, since the introduction of the SCR this layout is the most common format in use today.

The mains input is connected to a mains contactor to control the switching on and off of the regulator. The mains power is connected to the mains isolating transformer via the back-to-back connected SCRs.

The SCRs control the power into the mains isolating transformer. The secondary of the output transformer has tapping to allow adjustment of the output so that the maximum power rating of the regulator can be better adjusted to match the installed load. The output current then flows through the output links to the airfield circuit.

This current is monitored by a current transformer which provides feedback to the control circuit. The control circuit receives a command from the tower, or the regulators local control switch to provide a selected level of current that corresponds to the level of lighting required.

The control circuit compares the selected current/intensity level to the feedback from the CT. The result of this comparison is sent to the firing circuit of the SCRs to control the timing of the SCR triggering.

If the output current is less than the selected level of the control circuit it will cause the SCR is to fire earlier in half cycle and hence apply more energy into the circuit to increase the current.

If the output current is greater than selected, the control circuit will delay the firing of the SCRs to reduce the energy into the circuit and therefore reduce the current.

The output tappings should be selected so that when the maximum current (6.6 A) is selected, the regulator should be supplying a near full sinewave, with the firing of the SCRs occurring very early in the half cycle.

If a tapping is selected that is too low for the load connected, the regulator will fail to achieve the required full 6.6 amp current.

If a higher than required tapping is used, the regulator will operate ‘normally’. However, the firing of the SCRs will be delayed until very late in the cycle particularly on the lower current settings. This will result in a poor power factor, harmonics, and may cause the regulator to be unstable (although modern regulators can usually handle these conditions without any problem).

![Figure 5.7: Basic regulator operation](image-url)
Most modern regulators will incorporate several extra features as part of the control unit. These may include lamp failure detection, over voltage, over current and earth fault detection.

The regulators often incorporate several types of remote control such as direct wiring where each intensity is selected a separate hard connection or serial communication (such as Modbus Ethernet systems) which may be used in more complex systems.

5.5 Maintenance

Maintenance for MITs is minimal. Keep the transformer clean and well ventilated. Check current settings annually, or if loads have changed then set tappings accordingly.

Maintenance requirements for new CCRs is now minimal. Keep clean and well ventilated. Check circuit current settings annually. Check fault indicators annually.

5.6 Troubleshooting

For SITs and MITs, a fault can usually be found by isolating the transformer, and using an ohm meter to check the continuity of the circuit windings, or a ‘megger’ to test insulation to earth.

For CCRs, attempting fault finding poses some difficulties. Series current regulators are a closed loop device. That is, power is fed into regulator, the output is monitored and this adjusts the control. A failure in the equipment will often cause immediate shutdown making it difficult to fault find with the machine operating.

**WARNING:** THE FOLLOWING INFORMATION IS INTENDED FOR USE BY QUALIFIED ELECTRICIANS ONLY.

To begin fault finding start by:

» checking any indicator lights or alarm messages;
» check that mains is available;
» obtain clearance to place the regulator in local control; and
» then follow the supplier’s handbook instructions for fault finding.
### 6.1 Types of airfield lighting cable

**Primary cable**

The airfield lighting primary cable is the cable that connects the series current power source (MIT or CCR) to the SITs for the lights in the airfield lighting systems.

The standard airfield lighting primary cable is a single conductor cable of 6 mm sq of seven strands.

This cable is available in two voltage ratings 3 kV and 5 kV.

The older three kV cable has a stranded copper conductor ‘C’, polyethylene insulation ‘B’, and a black nylon outer sheath ‘A’. The nylon is to provide mechanical protection and protection from termites.

The 3 kV cable is generally used on installations up to 10 kW where the supply voltage is 1500 V.

The 5 kV cable was introduced to allow circuit loads above 10 kW with the resultant increased system voltage.

The 5 kV cable has a thicker insulation and can be provided with other options such as conductor and insulation stress relief layers, and outer conductive screens.

Two examples of 5 kV airfield lighting primary cable are shown below.

Where primary cables with metallic screens are used the metallic screen must be earthed. This requires a special jointing arrangement.

**Secondary cable**

The secondary cable which runs from series isolating transformer to the light fitting is usually a twin core figure-8-style cable with PVC insulation and a nylon sheath for mechanical protection.

The standard wire size used to be 1.5 sq. mm but 2.5 and 4 sq. mm cable is available for longer secondary cable runs.

The selection of the size of this cable is dependent on the length of the cable run from the SIT to the light.
6.2 Cable joints

Cables come in lengths limited by the cable drum that they are supplied on. Cables must be jointed to other sections of cable and to SITs to allow the lighting system to work correctly.

Also, when a cable is damaged the cable must be repaired by locating the damaged section of cable, cutting out the damaged section, and joining the cable back together.

Cables can be jointed using different jointing methods. These include in-line joints and connection plugs and sockets to the cables.

These joints must be very carefully made to achieve a connection that is both electrically sound and provides the same level of insulation and waterproofing as provided by the cable.

The quality of these joints is the single most important factor in maintaining a high level of circuit insulation.

By its very nature the cable installation and jointing work must be conducted in the open in all kinds of weather and the cables are located in small pits and confined areas.

To make high-quality joints under these conditions requires absolute cleanliness of the cable and joint parts and careful attention to the way in which the work is conducted. Any contamination of the joint or poor workmanship will cause less than perfect results. It is particularly important to ensure that the cable joint preparation is undertaken during dry conditions or with suitable protection to ensure that there is no ingress of moisture into the cable joint during the jointing process.

This work is labour intensive and may be conducted under difficult conditions. The care and precision under which it is undertaken will have a very significant effect on the quality of the whole installation. The insulation levels required on installations today is much higher and must be maintained over time at levels that were previously considered unobtainable.

3 KV cable joint.

The 3 KV cable jointing kit V10/386D is pictured in Figure 6.4. This provides an in-line joint for the 3 kV cables.

This kit contains the materials needed to make a joint on the Australian 3 kV cable. It does not contain any materials for cleaning the cable prior to making the joint. A cleaning cloth and alcohol wipes will also be needed to make a joint using this kit.

The kit contains:

» one 6 mm in-line crimp lug;
» one 10/3 mm heat shrink tube; and
» one 16/5 mm glue lined heat shrink tube.

**WARNING:** Ensure the circuit is properly isolated, earthed and tested prior to commencing any work or touching the cable. The following information is for use by qualified electricians only.

Figure 6.4: 3kV primary cable heat shrink jointing kit
5 kV cable joint.

The 5 kV cable joint kit AUST-APL/1 pictured in Figure 6.5 contains the materials needed to make a joint on 3 and 5 kV cable. This provides an in-line joint for the 3 kV cables. This kit is intended for use on cable that does not have an earth’s screen.

The kit contains:
» one alcohol wipe;
» one strip of emery cloth;
» one 6mm in-line belled-end crimp lug;
» one piece of mastic tape;
» one 24/6 mm heat shrink tube 100 mm long; and
» one 16/4 mm heat shrink tube 210 mm long

**Figure 6.5:** 5 kV primary cable heat shrink jointing kit

**WARNING:** Ensure the circuit is properly isolated, earthed and tested prior to commencing any work or touching the cable.
6.3 Cable connector kits

Cable connector kits are available for primary cables (for both unscreened cables and cables provided with metallic screens) and for secondary cables.

Care must be taken when purchasing connector kits to ensure that the correct type of kit is obtained for the particular type of cable being used.

Primary connector kit

It is important to check carefully when purchasing any primary connector kits as they can differ depending on the conductor size, the diameter of the cable insulation and the overall diameter of the cable. An example is provided in Figure 6.6.

Please request installation instructions from the manufacturer and follow the manufacturers requirements.

Secondary Connector Kit

It is important to check carefully when purchasing any secondary connector as they can differ depending the style of secondary cable being used. (e.g. single core or two core, conductor size etc.) An example is provided in Figure 6.7.

Please request installation instructions from the manufacturer and follow the manufacturers requirements.

Figure 6.6: Typical primary connector kit for unscreened cable

Figure 6.7: Typical secondary connect kit for two core cable
7. TAXIWAY LIGHTING

These notes should be read with reference to MOS-139 Chapter 9.13.

7.1 Overview

Taxiway lighting is part of the visual guidance lighting used on the simplest lighting installation at all levels to the most sophisticated lighting installation used to guide aircraft in very low visibility operations.

The taxiway lighting will comprise of sub systems to form the taxiing guidance. These may be as simple as edge and hold position lights only or include additional subsystems as listed below:

- Taxiway edge lights
  Taxiway edge lights are usually elevated and blue in colour. Low and medium intensity lights are omnidirectional and elevated. Edge lights are single stage low intensity or three-stage medium intensity.

- Taxiway centreline lights
  Taxiway centreline lights are inset lights and green in colour.

- Exit lights
  Exit taxiway lights are inset taxiway centreline lights directing aircraft off the runway onto the taxiway. These lights are green then yellow alternating from the runway centreline to the edge of the flight strip.

- Intermediate hold position lights
  Intermediate hold position lights are yellow lights located at the runway holding points on the taxiways leading onto the runway and at intermediate holding positions located around the airfields.

- Stop bar lights
  Stop bar lights are red in colour and located in a line across the taxiway at runway holding positions.

- Runway guard lights
  Runway guard lights are flashing yellow lights at runway holding positions, either elevated edge or inset across the taxiway.

- Retroflective taxiway markers
  These are permitted by the MOS on Code A and B taxiways.

The layout and performance of these systems will vary to meet the overall performance requirements of the taxiway lighting in accordance with the requirements described in the relevant standard.

Taxiway lighting is used to guide the aircraft to the runway from the apron and from the runway to the apron.

It must be identified on the runway during the rollout of the aircraft with sufficient time to allow the pilot to steer the aircraft safely onto the taxiway.

The lighting must then guide the pilot through curves and intersections with other taxiways and runways to bring the aircraft to the apron while avoiding leaving the pavement or colliding with building, equipment or other aircraft in the movement area.

In Australia taxiway edge lighting is usually used on only the most simple of taxiway layouts. Row effect is an important factor to make judgement of the aircraft’s position.

Figure 7.1: Taxiway edge lights
In low visibility, as the number of lights visible to the pilots is decreased, so the row effect will be much less effective. Any curves or intersections will be difficult to follow and loss of effective guidance can leave the pilot disoriented.

In low visibility, complex edge lighting can become a sea of blue light with little intuitive guidance provided.

It is in these conditions that the serviceability and consistency of performance of each light is most important.

The quality and reliability of this information is dependent on the serviceability of each fitting to give reliable information and not mislead the pilot.

Each fitting must be correctly installed, levelled, clean, functioning correctly and not obscured by grass or other objects in any direction for several metres.

Where the taxiway system is more complex with curves, intersections and multiple routes, taxiway centreline lights give greatly improved guidance.

The centreline lights are directly in front of the pilot and generally more closely spaced. The pilot experiences a very intuitive line of lights to follow without the need to judge the aircrafts position between two rows of lights on each side of the aircraft.

7.2 Configuration

Taxiway edge lights

The edge lighting is located near the edge outside the designated taxiway.

This may be outside the pavement or on the pavement where a seal has been used to reduce erosion of the soil by jet blast or prop wash. Some taxiways may be marked on large areas of pavement such as aprons or hardstands.

The spacing of the lights is up to 60 metres on long straight sections of taxiway but reduced on shorter sections or around bends. The lights are located in pairs on each side of the taxiway. On bends the lights are located on each side of the taxiway on radials from the centre of the curve.

The edge lights will also be used to mark the edge of turning nodes on runways and the edge of aprons where the apron is not well lit or the apron edge is not clearly identified.

Edge lighting may also be used in conjunction with centreline lights to mark the edge of sections of taxiway where there is difficulty in identifying the edge such as corners.
Figure 7.4: Typical taxiway edge light layout
**Centreline lights**

The centreline lights are located along the taxiway centreline with spacings similar to edge lights with larger spacing on long straights and reduced on curves. Because centreline lights are used on airfields operated in lower visibility and with complex taxiway layouts, the spacing can be further reduced to as small as 7.5 metres.

Centreline lights extend onto the runway to mark the path onto the runway for take-off or to guide the pilot from the runway to the taxiway.

Runway exit taxiways are of two types:
- Low speed exits intended to be used when an aircraft has slowed to normal taxing speed and are usually a 90 degree turn from the runway.
- Rapid exit taxiways that are intended to allow the aircraft to exit the runway at higher than normal taxi speed and continue to slow on the taxiway. This type of exit allows the runway to be cleared more quickly and ready for use by another aircraft and so increasing the efficiency of the airfield. Rapid exit taxiways are a gentle sweeping curve from the runway. The rapid exit taxiway lights extend along the centre of the runway for 60 metres prior to the commencement of the exit curve to give the pilot warning of the impending exit.

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*Figure 7.5:* Typical taxiway centreline light layout
Intermediate hold position lights

Hold positions are the point on a taxiway that marks the limit an aircraft may travel before receiving clearance to enter a runway.

The intermediate position lights are either elevated or inset yellow lights.

- Edge hold position lights are usually elevated and are provided on each side of the taxiway in line with the taxiway edge lights. These lights are of the same type of fitting type as the taxiway edge lights but are fitted with a yellow lens.

- Hold position lights provided on taxiways with centreline lights incorporate three unidirectional inset lights across the taxiway facing the direction of the aircraft approaching a runway. The centre light of the three lights is located in line with the taxiway centreline lights, the other two lights are located 1.5 m either side of the centre lights.

Stop bars

Stop bars are provided on taxiways for low visibility operation and incorporate a row of inset red lights across the taxiway to control the access of aircraft onto the runway.

Stop bar lights are controlled by ATC. The taxiway centreline lights leading onto the runway for a distance of at least 90 m past the runway lead onto the runway are controlled in conjunction with the stop bar lights such that when the stop bar lights are ON, the taxiway lead-on lights are OFF.

When an aircraft is cleared to proceed the stop bar is turned off and the lead-on centreline lights come on.

Runway guard lights (wig wags)

Runway guard lights are used on taxiways either on each side of the taxiway or inset units across the centreline of taxiway.

They are visible to aircraft approaching the runway. The operating guard lights indicate not only that you are approaching a runway but importantly that the runway is active (in use).

They are flashing yellow lights and used on airfields operated in low visibility. See MOS-139 9.13.6

Runway guard lights are required to be switched on whenever the runway is active. Note that in practice, this means at all times unless it has been taken out of service.

7.3 Maintenance

Elevated fitting maintenance inspection and repair work should include:

- Inspecting glass wear (lens) for breakage, sand blasting, rubber and dirt.
- Checking lamp condition and function, including checks for etching of the envelope and damage/corrosion of the lamp base or leads.
- Lamp holder condition.
- Light base and frangible mounting.
- Checking level and alignment using the correct instrument for the fitting.
Inset fittings are best serviced in the workshop and only replaced in the field with a changeover unit as dismantling is difficult and time consuming in the airfield environment.

The time to have the base unit open may be short and a base cannot be left open while aircraft traffic along the taxiways.

Inset fitting maintenance inspection and repair work should include:

» Inspecting glass lens for breakage, chipping, sand blasting and dirt around the lens.
» Inspecting and changing seals and gaskets in accordance with the manufacturer’s recommendations.
» Checking filters for damage.
» Checking lamps or LEDs for serviceability and condition.
» Checking all mechanical parts for corrosion and sound condition. These lights are subject to high loading and must be in good condition and the mountings sound so as not to constitute a hazard to aircraft.
» Checking all hardware (screws and bolts) that they are in place and the threads are not stripped.
» Cable glands must be tight and no water should be able to enter the fitting.
» Cable plug and socket must be clean and fit tightly.
» The inset base unit must be tight in the ground, level and the mounting studs or bolts in good order.

Note: Great care must be taken to ensure that inset lights are replaced using the correct type of inset light with green and yellow lenses correctly oriented. Some manufacturers have inset lights with lenses that emit light at 180 degrees for straight taxiways. Curved sections of taxiways have lights with lenses that are required to be angled to orient their output for the direction of the curve (left or right). These lights are generally marked with a dot or a line of green or yellow of paint on their surface to indicate the direction of the light and the colour.

Make sure that inset light tops are tightened with a torque wrench to the manufacturers specifications.
8. RUNWAY LIGHTING

8.1 Overview

This section should be read with reference to the applicable standard MOS Part 139 Ch 9.10.

Runway edge lighting is the most fundamental form of airfield lighting that forms the basis of any airfield lighting installation.

The edge lighting is made up of four sub components. These are:

» **Runway edge lights**
  Runway edge lights are elevated or inset, and white in colour. The exception is instrument precision approach runways which are yellow for the last 600 m.

» **Threshold lights**
  Threshold lights are green in colour, elevated or inset.

» **Runway end lights**
  Runway end lights are red in colour, elevated or inset.

» **Runway centreline lights**
  Runway centreline lights are white and red in colour, or inset.

The layout and performance of these systems will vary to meet the overall performance requirements of the runway lighting in accordance with the requirements described in the relevant standard.

The edge lighting is used by the pilot in both take-off and landing and provides the pilot with information as to the start and finish of the usable runway length and width.

In take-off the pilot can judge the location of the aircraft on the runway by its alignment to the runway and identify the runway end. The aircraft will be affected by cross winds and the pilot’s ability to react will be dependant on the number of lights that can be seen that will indicate the edge of the runway. Row effect is an important factor to make judgement of the aircraft’s position. In low visibility as the number of visible lights is decreased so the row effect will be much less effective. It is in these conditions that the serviceability and consistency of performance of each light is most important.

8.2 Configuration

The appearance and arrangement of the runway lighting is the same from the most basic runway to the highest level of facility and low visibility CAT III runway. However, the light fitting type and the number of intensity settings for the lighting will change to suit the specific installation.

The runway lighting is provided with threshold lights, runway edge lights and runway end lights.

The longitudinal spacing of the runway edge lights is a maximum of 60 m and no less than 55 m.

The lateral spacing of the lights for runways of less than 30 m is the same as for a 30 m runway (i.e. 0-3 m outside a runway. Typically, the lights are placed laterally at 32 m). For larger runways 45 m or 60 m the lights are placed not more than 3 m from the runway edge.
8.3 Characteristic

**Runway edge lights**

Runway edge lights for non-instrument runways are white in colour. Instrument precision approach runways required the last 600 m prior to the runway end of the runway edge lights to show yellow in colour.

Lights for low and medium intensity lighting are omnidirectional. The omnidirectional lens provide for circling guidance.

High intensity lights are unidirectional. Some high intensity units have bidirectional beams with a supplementary. For intensity controls, see MOS-139 Chapter 9.1.14

**Threshold lights**

Threshold lights are green in colour and either elevated or unidirectional inset lights except the outer threshold light which in Australia is omnidirectional and elevated.

The threshold lights will have intensity and control to suit the runway edge lighting installed. This is required to be ratio of 1:1.5 of the runway edge lights.

Threshold lights are usually a row of green lights spaced equally across the runway at the threshold.

The number of lights provided for the threshold lighting is dependent on the type of lighting systems (low intensity, medium intensity or high intensity) and the width of the runway for high intensity systems.

**Runway end lights**

Runway end lights are red in colour and either elevated or inset lights.

The end lights will have intensity and control to suit the runway edge lighting installed. This is required to be a ratio of 0.25:0.5 of the runway edge lights.

Note: in Australia low intensity installations may use elevated runway end/threshold split-lens fittings where the runway end and threshold are co-incident. For medium intensity and above, inset lights are more common. The exception to the latter might be where the runway elevation drops such that inset lights cannot be seen for a sufficient distance. If in doubt, refer this to your CASA inspector.

See MOS-139 Chapter 9.3.10 for spacing details.

**Runway centreline lights**

Runway centreline lights are provided for instrument precision approach runways used for aircraft departures intended for use in visibility conditions down to runway visual range (RVR) conditions of 350 m. Runway centreline lights should be installed along the runway centreline at equal spacings of 30 m, 15 m or 7.5 m depending on the visibility conditions in which they are intended to be used for. Runway centreline lights white in colour up to 900 m from the runway end, alternate red white from 900 m to 300 m from the runway end, and red for the last 300 m prior to the runway end.

High intensity inset threshold lights have a characteristic that aims the beam towards the centreline of the runway and so the units close to centreline are straight ahead with units toed left and right towards the side line. Care must be taken to replace units with the correct toe in when conducting maintenance.
Figure 8.1: Typical non-instrument runway layout (CHECK DETAILS OF DIAGRAM)

- Uniform longitudinal spacing 60 m
- 2 elevated unidirectional threshold light units (green)
- 6 Bi-directional threshold and runway end light units - red to departing aircraft and green to landing aircraft

Legend:
- Green light
- Red/Green light
- White light
Figure 8.2: Precision approach runway layout (CHECK DETAILS OF DIAGRAM)
8.4 Displaced thresholds and stopways

The threshold of a runway is not necessarily located at the start of the pavement. The threshold may be located at a point several hundred metres from the start of the pavement. This can be done for various reasons such as:

» To give safe clearance over obstacles in the approach to the runway.

» A displaced threshold may also be introduced if the pavement at the end of the runway is no longer able to sustain the continuous impact from landing aircraft.

Departing aircraft are able to use the displaced section of the runway for take-offs or landing rollouts when landing from the opposite direction because those aircraft are not impacting the runway with the force of a landing aircraft or affected by obstacles beyond the runway.
8.5 Temporary displaced threshold

The threshold of a runway may be displaced temporarily to allow works to be conducted in on the threshold area or the pre-threshold. The touchdown zone of a runway is the area most subject to damage and wear and so it is not unusual for this area to be closed for repair while maintaining the runway in operation with a reduced length.

The layout of lighting patterns suitable for permanently and temporary displaced threshold are described in MOS-139 Chapter 9.12-4

8.6 Stopway (runway end) lights

Stopways are an extension of the runway and when provided are there to increase the effective length of the runway in relation to the distance available for an aircraft to accelerate for take-off then abort and stop.

Stopway lights are unidirectional red lights aimed in the direction of the aircraft on a take-off run to give guidance throughout the aborted take-off rollout.

Refer to MOS-139 Chapter 9.12-5

8.5 MAINTENANCE

Elevated fittings

Elevated fittings maintenance inspection and repair work should include:

» Inspect glass wear (lens) for breakage, sand blasting and dirt.

» Lamp or LED condition including is it functioning? Is there evidence of etching of the envelope and damage / corrosion of the lamp base or leads?

» Lamp holder condition.

» Light base and frangible mounting.

» Check that where two coloured lenses are utilised that they are reassembled with the lens colour in the correct position

» Check level and alignment using the correct instrument for the fitting.

Inset fittings

Inset fittings are best serviced in the workshop and only replaced in the field with a changeover unit as dismantling is difficult and time consuming in the field environment. The time to have the base unit open may be short and a base cannot be left open while aircraft traffic occurs.

Inset fitting maintenance inspection and repair work should include:

» Inspecting glass lens for breakage, chipping, sand blasting and dirt around the lens.

» Inspecting and change seals and gaskets in accordance with the manufactures recommendations.

» Checking filters for damage.

» Checking lamp for serviceability and condition.

» Checking all mechanical parts for corrosion and sound condition. These lights are subject to high loading and must be in good condition and the mountings sound so as not to constitute a hazard to aircraft.

» Checking all hardware (screws and bolts) that they are in place and the threads are not stripped.

» Cable glands must be tight and no water should be able to enter the fitting.

» Cable plug and socket must be clean and fit tightly.

» Checking that where two coloured lenses are utilised that they are reassembled with the lens colour in the correct position.

» The inset base unit must be tight in the ground, level and the mounting studs or bolts in good order.

Note: Great care must be taken to ensure that inset lights are replaced by the correct type of inset light.

Make sure that inset light tops are tightened with a torque wrench to the manufacturer’s specifications.
9  APPROACH LIGHTING

9.1  Introduction

High intensity approach lighting systems are used in conjunction with high intensity runway lighting to enable aircraft landings to be made in adverse weather conditions. These lighting systems are also used for approaches in good visibility conditions where extraneous lighting around the airport could cause conflicting information to a pilot.

These systems can also provide centreline and roll guidance at airports where there is no background lighting. They also provide a terrain reference in the form of lights, giving the pilot a threshold reference level. The most common system used in Australia is called the Calvert centreline and cross bar system.

The approach lighting can be installed as two different systems, CAT I and CAT II. With the CAT I system the minimal weather conditions an aircraft is allowed to land in is at decision height of 60 m and in visibility conditions down to 800 m or in RVR conditions down to 550 m. The CAT II system allows landings with both a reduced decision height and runway range, the decision height is now 30 m with an RVR conditions down to 350 m.

Where CAT II systems are utilised, touch down zone (TDZ) lighting is required to be provided. TDZ lighting incorporates two rows of lights (barrettes) either side of the runway centreline at 30 m intervals extending from the runway threshold for a distance of 900 m from the runway threshold.

9.2  Configuration

Both CAT I and CAT II systems consist of a line of lights being an extension of the runway centreline extending up to 900 m beyond the runway threshold and five crossbars of lights at right angles to the centre line. Figures 9.1 and 9.2 show plan views of both systems.

As can be seen from Figures 9.1 and 9.2 the crossbars which are at right angles to the centreline are designed to form decreasing bars of lights referenced to a point of origin 300 m after the runway threshold.

These give an arrowhead pointer reference to the runway centreline. This enables the pilot to line up on the runway centreline when the weather conditions may not permit good visual references from the runway. The bars also provide roll guidance in conditions where other visual references are not available.

Where required, the position of these crossbars may be altered to avoid roads, fences etc. which may run through the system.

Ideally, the entire approach light system should be kept at the same level as the runway threshold. However, where the ground slopes above or below the threshold level there are allowable rising and falling gradients at which the lights can be installed.

For tolerances see MOS-139 Chapter 9.7 and the appendices in ICAO Annex 14.

Note: Reduced length approach lighting systems may be approved by CASA in some instances.

9.3  Light direction and elevation angles

The light units are a fixed unidirectional beam directed along the approach to the runway. The light beam is parallel to the runway centreline and the lights are elevated at an angle so that the centre of the beam intersects the three degree glideslope angle at 750 m from the source of the beam. The angle of elevation of the light will depend upon the distance the light is from the touchdown point and the position of the light with reference to the threshold level. A special alignment tool is usually provided by the suppliers, for installation and subsequent maintenance.

9.4  Colour and light intensity

White light is the only colour used in a Category One approach light system. The intensity of the light is controlled and six separate intensities of light can be selected. These intensity selections range from 100% down to 0.3% in the following steps: 100%; 30%; 10%; 3%; 1%; and 0.3%. Each step is one third of the previous intensity as it steps down through the available range. The intensities would be selected to suit the weather conditions; the ultimate decision being made by the pilot of the approaching aircraft.
9.5 Light pattern

**Category One systems (CAT I)**

The CAT I system uses a coded centre line. The code changes every 300 m. As can be seen in Figure 9.1, the centreline consists of one light for the first 300 m from the threshold, the next 300 m two lights and the final 300 m three lights.

**Category Two systems (CAT II)**

The CAT II approach light system is laid out the same as the Category One system with the addition of extra lights in the centreline starting at the runway threshold and extending for 600 m.

In addition are side rows of lights from the threshold to a point 300 m out. These side row lights display red light as illustrated in Figure 9.2.

A typical Inner 300 m approach and runway lighting for precision approach runways, categories II and III including the TDZ lighting can be seen in Figure 9.3.

9.6 Maintenance

For maintenance and troubleshooting of circuits, see Chapter 5.

For light units, ensure lenses are clean and free of sandblasting. Ensure all connections are good and repair if needed. Replace any unserviceable or blackened lamps. Level and align fitting in accordance with manufacturer’s recommendations.
Figure 9.3 Typical inner 300 m of CAT II and CAT III

- Runway edge light
- Runway centre light
- Runway touchdown zone light (TDZ)
- Threshold lights spacing 3m max
- Side row barrette
- Equal to that of ‘TDZ’
- Crossbar
- Either single light source or where the centreline beyond 300 m from the threshold consists of barrettes, centreline barrette
- Crossbar

- 3.0m – 4.5m
- 15m invisibilities below 350m RVR
- 60m max
- 18.0m – 22.5m
- 18m preferable
- 4m
- 150m
- 300m
- 60m
- 30m

- Runway
d- Runway light (TDZ)
10. PRECISION APPROACH PATH INDICATOR SYSTEM (PAPI)

10.1 Standard reference
These notes should be read with reference to the applicable standard for Australia, MOS-139 Chapter 9.9.4

10.2 Background
To avoid confusion between different systems a bit of history is worth noting. Research conducted in the years after the second world war into the safety of aircraft operations found that the most dangerous part of any flight was the landing phase.

The most common cause of accidents was found to be pilot error due to the pilots inability to safely control the glide path to touchdown on the runway.

Radio aids were developed to guide the aircraft to a point where the pilot would obtain sufficient visual information to manually control and land the aircraft. These aids are essential in low visibility operations allowing the pilot to begin the approach to land without sighting the runway. These aids are relatively expensive to purchase and maintain and so are limited to major runways where closure of the runway would cause significant disruption to the airport and the economy of the city it serves, or military runways needing all-weather capability. Even with the use of instrument landing systems (ILS) the pilot needs to control the aircraft by visual reference in the final moments before touchdown.

These systems require specialist equipment on the ground in the aircraft and the pilot must be trained in its use along with all the skills needed for instrument flight.

A visual guidance system would give increased safety in the approach to land in better visual conditions where the runway is visible for several kilometres. This equipment could be used by all pilots without the need for the aircraft to be equipped with specialist navigational aids.

Although the runway may be visible to the pilot this does not mean that there is not considerable difficulty to safely assess the situation.

The conditions that a pilot must overcome are:
» night;
» lack of horizon;
» sloping ground;
» lack of visual information in the approach terrain;
» difference in height between the pre-approach and the runway;
» misleading visual information from significant features around the runway such as roads, tree lines, and hills;
» poor contrast in the visual segment; and
» the handling characteristic of the aircraft.

The visual guidance system must achieve four main points:
» clearance of obstacles in the approach to land;
» clearance over the threshold;
» descent at the correct angle; and
» touchdown at the correct point on the runway.

When a visual approach slope indicator system (VASIS) is deployed on both sides of the runway it will also give some roll guidance where a natural or reliable horizon is absent.

To be successful any VASIS must be intuitive, using visual skills of the observer that are repeatable under all climatic and geographical conditions and by all pilots regardless of age, gender or visual acuity within the range required for pilots.

The visual skills of the pilot that may be used are:
» colour;
» intensity;
» characteristic (steady or flashing, On or Off);
» alignment; and
» pattern or shape.

Not all these abilities of the observer are the same, as sensitive or repeatable across all people.
Colour is quite subjective between different observers and to be useful must be well defined so as not to be confused.

Intensity is not a very useful way to provide information as it is very difficult to tell the difference between quite different levels of brightness. Typically, less than a 50 per cent change is not able to be detected reliably.

Characteristic is a very sensitive skill repeatable from person to person and time to time. The presence of a light or a flashing light is very clear.

Pattern or shape can be very useful as long as the shape or pattern is large enough over distance.

The VASIS must give guidance by providing the pilot with certain information that gives feedback to the pilot of the aircraft’s position with respect to the ideal glide slope.

This information is:

» the aircraft is ON slope;

» the aircraft is above or below slope;

» how far from the correct approach slope; and

» how quickly this rate of change is occurring.

The first VASIS in widespread use was the red/white VASIS

This equipment provided basic control information of on slope, below slope, and above slope.

The limited information especially the rate of change and the fact that the red signal was a much lower intensity than the white meant that this system was less than ideal.

The basic design of the optical system provided a gradual change from red to white or white to red. This resulted in a wide range of subjective judgement as to when the change occurred and consequently a wide range of results from pilot to pilot.

This system had to be designed for only one size of aircraft, which at the time of design was not a significant problem, as the aircraft in service did not vary very much with respect to the wheel-to-pilot eye height. The introduction of larger aircraft like the 747 and DC10 with wheel-to-eye heights much greater than other aircraft meant that this equipment would bring the aircraft over the threshold with only limited clearance. A third set of lights could be added further along the runway from the top set to give an alternate glide path but with the loss of its simplicity and still limited information.

The next major development in VASIS design was the Australian T-VASIS.

![Figure 10.1: VASIS signals](image-url)
The T-VASIS was arranged to be similar to the information from the ILS equipment in an aircraft. It was in principle a white light presentation with lights being visible or not to indicate approach angle.

This equipment is very accurate and intuitive with simple components that operate reliably for many years. Its performance met all the requirements of on-slope, above and below slope with three indications of each which gave excellent rate of change information, plus a red signal to indicate a dangerously low angle.

The problem with this system is that it is made up of 20 light units on the side of the runway. The number of units and its associated equipment made it expensive to install and maintain. Modern airports rely heavily on the efficiency of the taxiway system to operate at peak number of movements per hour. The T-VASIS occupied a large amount of space near the ends of the runway and this is difficult to co-locate it within the needs of the taxiway network.

Many other forms of visual glide slope guidance have been developed around the world for specialist and military operations using a mixture of principles including flashing lights and alignment of lights.

The 1980s saw the introduction of the PAPI system. This system has become the most commonly used VASIS around the world today.

It is principally a red/white VASIS using graduated signals to give more information and a more sophisticated optical system to achieve rapid colour change to remove the subjective assessment by the observer as to when the colour change has occurred. Its layout is quite compact and therefore easier to locate along the runway without interfering with taxiways.
10.3 Configuration

The PAPI installation is made up of four identical light units. These light units are located at the side of the runway at the point of touchdown. The light units are laid out in a line at right angles to the direction of the runway and spaced at approximately 15 m from the edge of the runway the first unit and then at 9 m intervals between lights.

Each light unit is identified by a letter starting with the letter A at the extreme left of the runway, and if the installation is a double-sided PAPI then finishing with a letter H at the extreme right.

If a single-sided installation is used it will be located left side of the runway unless there is a significant engineering difficulty in locating it on the left. In these circumstances it may be located on the right.

A double-sided installation will perform as a mirror image left to right with the outer most units set to the lowest angle of approach.

Each light unit is comprised of two or three identical lamp filter lens assemblies. The decision to use two or three lamp assemblies is made with reference to the serviceability of the equipment. The loss of one lamp or filter in a two-lamp unit will render the unit unserviceable. The loss of one lamp or filter in a three-lamp unit is still considered serviceable. The decision to use a two or three lamp system will be made with consideration of the ability to monitor and make repairs to the equipment in service and the effect on the operation of the airfield. The first LED versions of the PAPI are now starting to come onto the market and are likely to replace lamp versions over time.

As already stated the light units of the PAPI are all identical and the angle of transition from red to white is set by the angle that the light unit is elevated. The exact angle may vary on some installations to suit obstacle clearance however the standard settings are:

- Unit A (H) 2’ 30"
- Unit B (G) 2’ 50"
- Unit C (F) 3’ 10"
- Unit D (E) 3’ 30"

These settings provide an on-slope indication of two red lights and two white lights at three degrees.

Figure 10.4: PAPI light unit location
Figure 10.5: Typical PAPI unit installation

Figure 10.6: Typical PAPI operation of optics

View from straight ahead focused just past the edge of the filter onto the reflector.

Looking down into the lens the observer’s sight is focused below the filter and white light will be seen.

Looking up into the lens the observer’s sight is focused onto the filter then through to the reflector and the observer will see red light.
### 10.4 Characteristics

The standard approach angle is three degrees and the signals of the PAPI are arranged so that the on slope signal at three degrees will show two white and two red lights.

- The two high signal is set at 3° 30 minutes
- The slightly high signal is set at 3° 10 minutes
- The slightly low signal is set at 2° 50 minutes
- The two low signal is saying below 2° 30 minutes
10.5 Installation

The location of the PAPI is determined with reference to several important considerations.

The PAPI must be located so that the guidance it gives will bring the pilot’s eye over the threshold at a safe height with consideration for the vertical distance between the pilot’s eye and the main landing gear wheels. This height is chosen with reference to the general size of the aircraft as laid out in the table below taken from MOS Part 139 9.9.4.

Consideration is also given for the presence of an ILS system on the runway concerned. Where an ILS is present the guidance from the PAPI must not conflict with the guidance from the ILS.

The actual location will also be affected by any slope on the runway. A runway with an uphill slope from the threshold will have the PAPI located at a closer threshold than a level runway. Conversely a runway that runs down from the threshold will result in the PAPI being located further from threshold.

The PAPI light units are generally located at the same height as the centre of the runway. However, if this is not possible, adjustment must also be made to locate the light units so that they appear to the pilot in the same location as if light units were positioned at the runway height.

<table>
<thead>
<tr>
<th>Eye-to-wheel height of aeroplane in the approach configuration a</th>
<th>Standard wheel clearance (metres)b</th>
<th>Special minimum wheel clearance (metres)c, d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to but not including 3 m</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>3 m up to but not including 5 m</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>5 m up to but not including 8 m</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>8 m up to but not including 14 m</td>
<td>9</td>
<td>6</td>
</tr>
</tbody>
</table>

a In selecting the eye-to-wheel height group, only aeroplanes meant to use the system on a regular basis shall be considered. The most demanding amongst such aeroplanes shall determine the eye-to-wheel height group.
b Where practicable, the standard wheel clearance shown in column (2) shall be provided.
c The wheel clearance may be reduced to not less than those in column (3) with specific agreement of CASA, where an aeronautical study indicates that such reduced wheel clearances are acceptable.
d Where the special minimum wheel clearance is provided at a displaced threshold it shall be ensured that the corresponding standard wheel clearance specified in column (2) will be available when an aeroplane at the top end of the eye-to-wheel height group overflies the extremity of the runway.
The amount of adjustment will be calculated using the approach slope angle. For an approach slope of three degrees, this adjustment will be calculated by the approach gradient 1:19. That is, with every metre difference in height the light unit must be located approximately 19 metres closer or further from threshold to maintain the appearance of being located at the runway height.

The PAPI light projector is very flexible in its use. Its light output is observed as red in colour below the centreline and white above the centreline. This allows the equipment to be positioned and adjusted so that the approach angle can be changed if necessary to accommodate pre-threshold obstructions. CASA permits approach angles of up to 3.5° for jet aircraft and up to 4° for propeller aircraft. This equipment can be very easily adjusted to accommodate a range of approach slopes by simply selecting angles for each unit around the mid-approach angle.

The units are then adjusted to these angles with no need to engineer any new equipment to accommodate the new approach light. The same units can also be used for helicopter approaches at much higher angles of approach.

To determine the location of the light units, a ground survey must be done to determine the levels of the land in the area where the units are to be located. The exact location of the units can then be determined in relation to the factors described above. Each light unit requires a concrete foundation to rigidly locate the units in place and to maintain accurate alignment. A pit will also be required to locate the associated transformers. Two transformers for a two-lamp unit or three transformers for a three-lamp unit.

As part of this ground survey your surveyor will need to take into consideration factors associated with the obstacle limitation surface to ensure compliance with respect to possible obstacle infringements.

The primary cabling for the PAPI will run from the ALER to the first PAPI box, and then each unit in turn. The installation may require all of the PAPI units to be cabled together on one circuit and one regulator or, where double sided systems are used, may require separate circuits, one for each side of the runway, supplied from separate regulators or MITs. This complicated installation will result in greater redundancy meaning that the loss of one source will not extinguish the entire system allowing for continued guidance pilot guidance to complete their landings.

For further design assistance refer MOS-139 Chapter 9.9, and ICAO Aerodrome Design Manual Part 4.
10.6 Maintenance

The visual approach slope indicator is the most accurate lighting system used in airfield lighting. Consequently, the maintenance and adjustment of this system must be undertaken with care and precision.

When undertaking a maintenance inspection on the PAPI, it is important to have a methodical approach to the work.

» To begin the inspection, start with the exterior of the unit.

» Examine the outer case for signs of damage, loose lips and breakage or sand blasting of the external glassware. Loose covers can allow the entry of insects and dirt. If not firmly affixed they can also cause light spill to escape from the unit which will result in light signals being observed at angles other than intended by the design of the equipment.

» The entry of dirt and moisture into the equipment can damage or impair the performance of the reflector or lamp. It can also effect the proper operation of the filter lens. Sand blasting of the front glass will also have a negative effect on the optical precision of the light signals and their transition.

» Check mountings and hardware for corrosion, breakage and loose fixings. Any movement in the mountings can cause changes in the angle of operation of the light unit. No movement in the mounting unit can be tolerated at all as rigid fixing is vital to ensure the precise angles of operation of the PAPI.

» Check the cables for deterioration and damage.

» Remove the outer cover and examine the interior light for dirt and moisture damage.

» Examine all the interior hardware for loose or broken fixings.

» The precise operation of the change of angle the light signal is dependent upon the precise location of the filter and the rigid fixing of this with respect to the lens.

» Check and clean the lens making sure the lens is not cracked or loose.

» Check the filter to make sure it is correctly positioned in the filter holder and that the filter is not cracked, chipped or damaged in any way.

» Check that the lamp is operational, that the envelope is clear and that the lamp is correctly located in the lamp holder.

» To adjust or check the correct setting of the light angle will require a clinometer specific to the model of PAPI you are going to check. You’ll also need to know the angle setting of the PAPI light as commissioned.

» The standard settings are for a three degree PAPI are as below.

**Port side (left observed from threshold)**
- Box A: 2° 30 minutes
- Box B: 2° 10 minutes
- Box C: 3° 50 minutes
- Box D: 3° 30 minutes

**Starboard side (right observed from threshold)**
- Box E: 3° 30 minutes
- Box F: 3° 10 minutes
- Box G: 2° 10 minutes
- Box H: 2° 30 minutes

Where a non-standard approach angle has been used you will need to know the setting of each box before you can perform the adjustment of this equipment.

It is good practice that the setting angles of each unit are permanently marked with an engraved label fixed to the foundation or inside the unit.

To set the approach angle you need to firstly cross-level the light unit. This is done with a small bar level that is fitted onto the machined pads of the PAPI box main frame. It is good practice to always place this level on the frame the same way around and move it to the left or right so that it is positioned in the same place each time. The cross-level adjustment is performed by adjusting one of the front legs. It is good practice to maintain one leg as a fixed reference and to make all adjustments on the other leg. This adjustment is not required to achieve the same accuracy as the vertical angle adjustment. It is only necessary to adjust the cross-level so that the bubble is within the centre marks. The accuracy of the PAPI signals is not greatly dependent on the accuracy of this horizontal adjustment. However, cross levelling should be done to achieve a sharp transition red to white.
Once this adjustment has been completed the clinometer can be adjusted to set the angle required for that light unit. The clinometer is then fitted to the machined pads on the PAPI box main frame with the high end of the clinometer towards the rear of the light. The rear leg is used to adjust the angle of the PAPI light so that the bubble in the level of the clinometer is perfectly centre. The setting of the clinometer and the vertical adjustment of the box is critical to the accuracy of the PAPI.

During commissioning or when a flight test is performed, the pilot of the aircraft will fly across the signal of the PAPI to check the even distribution of the signal left and right. The flight check will also test the even progression of signals in the vertical and that there is no asymmetry of signals on a double-sided PAPI installation. If an ILS is installed, it will also check for harmonisation with the standard glide slope.

NOTE: Asymmetry is the term used to describe the condition when the PAPI indication on one side of the runway is different to the other side.

Figure 10.13: Typical PAPI Clinometer and tools
11. MOVEMENT AREA GUIDANCE SIGNS (MAGS)

MAGs are required at more complex airports and provide assistance to pilots to navigate their way around the movement area, as well as providing supplementary information.

11.1 Types of MAGS

Mandatory

These are white letters on a red background. Mandatory signs include runway designation and intersection, CAT I, II, and III designation, hold positions, no entry and vehicle stop signs.

Information

These are yellow letters on black background to signify location, and black letters on yellow background to signify direction. These signs can indicate taxiway location and direction, runway exits, apron directions, etc.

Where MAGs are required to be used at night they can be internally illuminated. If they are not, then they must be made of retro-reflective materials. Specifications for sign requirements are contained in MOS-139.

The illuminated MAGs were originally powered by filament lamps or fluorescent tubes powered with either their own, or a mixed series circuit (e.g. taxiway/MAGS light circuits).

It is now common to see MAGs lit by LEDs. These may utilise panels of LEDs or 'edge lit' LED panels.

Some common issues are balancing the minimum distance permitted from the pavement with the wind loading and therefore frangibility.

While the specifications may look cumbersome, most vendors these days have software applications available to perform the tedious design work.

11.2 Maintenance

This is much the same requirement as for elevated edge lights and related circuits.

» Isolate the MAG before performing any work (use local switch if provided).

» Clean panels with clean, dry cloth. Note that while most panels are UV stabilised, in practice their life is typically around 7 years after which panels may fade and need replacement.

» Replace lamps or LEDs as required.

» Ensure mountings have not worked loose and torque if required.

» Circuits – refer to Chapter 5.
12. MOUNTING FOR ELEVATED AND INSET LIGHTS

12.1 Mountings for elevated lights

Elevated fittings are installed in one of three basic methods. There may be minor variations on these and that is normally acceptable.

» Mounted on a tripod plate and wired to its SIT and located remote to the light.

» Screwed directly into a 2” British Standard Pipe (BSP) or National Pipe Straight (NPS) socket with a remotely located SIT.

» Mounted on a cover plate bolted to an Federal Aviation Administration (FAA)-type deep-base can with the SIT housed below the fitting.

Elevated lights and supporting structures where located with runway and taxiway strips must be frangible. These can take many forms from shear grooves, to breakable fibreglass structures. Suppliers should be able to provide certificates for your records.

Figure 12.1: Examples for installing elevated lights

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MOS Part 139 EXTRACT

9.1.11 Light Fixtures and Supporting Structures

9.1.11.1 All aerodrome light fixtures and supporting structures must be of minimum weight while being fit for the function, and frangible.

Notes:

1. For guidance on frangibility, see:
   a ICAO Aerodrome Design Manual Part 4 – Visual Aids, Chapter 15, Frangibility of Visual Aids; and

2. See Subsection 11.1.4A for information regarding siting of equipment and installations on operational areas.

Figure 12.2: Example of frangible approach masts
12.2 Mounting for inset lights

Inset lights can be mounted in two variations:

» shallow base with the SIT remotely located; and
» bolted to the cover of an FAA deep base with the SIT below.

Figure 12.3: Example of shallow inset base

![Diagram of shallow inset base]

Figure 12.4: Example of deep inset base

![Diagram of deep inset base]
13. ILLUMINATED WIND DIRECTION INDICATOR (IWDI)

Illuminated wind direction indicator(s) are to be provided at every aerodrome intended for use at night.

An illuminated wind direction indicator consists of a conventional canvas wind sock floodlit from above.

Runways intended for night operation by RPT aircraft must be provided with wind indicators at:
- each end of runways used by RPT jet aircraft;
- each end of runways used by RPT propeller-driven aircraft where the strip length is greater than 1500 m; and
- the end of a runway where a straight-in landing can be made off an instrument approach.

Each illuminated wind indicator must be installed in a conspicuous position on the aerodrome, having due regard to obstruction marking surfaces, and in such a way as to be free from the effect of air disturbances caused by nearby objects.

Illuminated wind indicators serving particular runways should be located 100 metres upwind of the thresholds, on the left-hand side of the approaches where practicable and outside the runway strip.

If an aerodrome is served by only one illuminated wind indicator it should be located in a conspicuous position, central to all runway thresholds.

You need to be mindful of the 1:7 obstacle limitation zone and with wind indicators typically 8 metres in height they need to be placed at around 56 metres outside the flight strip (taking into account rise and fall for the terrain) so as not to infringe on any obstacle limitation zone.

Most IWDIs in Australia in practice use four pairs (eight lights) to meet CASA lighting requirements for this equipment. Please refer to MOS-139 Chapter 9.6

13.1 Control

Illuminated wind indicators are normally connected to a separate power source.

Where only one wind indicator is provided and there are two or more lit runways, then control for the wind indicator needs be incorporated in the runway lighting control for each runway.

Where more than one wind indicator is provided, then control for each wind indicator needs be incorporated in the runway lighting control(s) for the operationally related runway(s).

13.2 Maintenance

Care should always be exercised when lowering the mast for maintenance or other purposes.

» Unplug the power supply for the moveable section of the mast from the mast supports. Check that there is no obstruction in the area where the mast will be lowered e.g., marker cone or parked vehicle.

» A rope of sufficient length is to be secured to the mast and the strain taken up on the rope before the securing pin is unlocked and removed. Slowly lower the mast until it has been firmly seated on the ground. After completing the required task, repeat the procedure in reverse order.

» Before leaving the site check that the wind sock is free from any snags and that all lamps are operational.
Figure 13.1: Mid-hinged illuminated wind indicator (IWI)

Illuminated Wind Indicator
Height approx 8m

Mid-hinged column type

White or another conspicuous colour for ?? wind sock, and yellow for ?? wind sock
14. ROTATING BEACONS AND OBSTRUCTION LIGHTING

14.1 Rotating beacons

In Australia, the need for a rotating beacon is normally advised by CASA. When required they are normally installed on the roof of the ATC tower, but this is not exclusively so.

There are three main types in existence. A 36” diameter DCB36, a 10” diameter DCB10, and four-headed sealed beam units.

The larger DCB36 unit is mainly installed at international airports, and being international have the colour code green/white in alternate flashes.

The smaller DCB10 and sealed beam models are more often found at regional airports and have the colour code of white flashes only.

The DCB36 and DCB10 units are now obsolete and are being replaced by the newer multi-head type units.

For further information, refer MOS-139 Chapter 9.5.

14.2 Obstruction lighting

It is the policy of the Civil Aviation Safety Authority to investigate all new constructions which could be potential hazards to aircraft movements.

CASA may, under the Air Navigation Act, prohibit any new constructions above certain heights near aerodromes. It may also order the removal or modification of an existing construction if it impinges certain clearance planes or order the lighting and/or marking of such constructions.

Obstacle identification by lights

An obstacle may be marked by either low, medium or high intensity obstacle lights. It may also be marked with a combination of these lights.

Low and medium intensity lighting is used for the identification of obstacles at night only. High intensity obstacle lighting is used for both day and night operations. The number of light units used to identify an obstacle will depend upon its location with respect to flight paths etc.
**Low intensity obstacle lighting**

Low intensity obstacle lights on fixed objects shall be fixed red lights having an intensity sufficient to ensure conspicuity considering the intensity of the adjacent lights and the general level of illumination against which they would normally be viewed. They shall emit aviation red in all directions in azimuth, from three degrees below to 90 degrees above the horizontal. The intensity of the lights shall not be less than 10 candelas of red light in the required direction. New installations shall have a peak intensity of not less than 100 candelas of red light.

**Medium intensity obstacle lighting**

Medium intensity obstacle lights shall be flashing red lights. The flash frequency shall be between 20 and 60 flashes per minute with an ON period of approximately twice the OFF period. The effective intensity of the flash shall not be less than 1600 candelas of red light and the light distribution shall cover all directions in azimuth, and from one degree below to 90 degrees above the horizontal. The lamp units will always be a double unit, and when used in conjunction with high intensity obstacle lights the light output will be white light.
LED lighting for low and medium intensity obstruction lights

Low and medium obstructions lights are now usually available with LED light sources.

High Intensity obstacle light

High intensity obstacle lights shall be flashing white lights. The flash frequency shall be between 40 and 60 per minute. All high intensity obstacle lights on the same object shall flash simultaneously. The effective intensity flash luminance shall be:
- day, 200,000 candelas minimum
- twilight, 20,000 candelas ± 25%
- night, 4,000 candelas ± 25%

Figure 14.7: Strobe based high intensity obstacle light

Location of obstacle lights for temporary obstacles

Depending on the nature and location of the obstacle, temporary low intensity obstacle lighting may need to be provided on the top of the object, associated equipment or cranes, while the obstacle is present at night.

Vehicles and some other mobile objects on the movement area of an aerodrome are obstacles. They need to be lighted in accordance with the requirements of CASA regulations, if the aerodrome is used and these obstacles are present at night. Typically, these are yellow flashing lights for vehicles.

Permanent man-made obstacles

All non-frangible elevated objects which are closer to the edge of a taxiway than the minimum distance between a taxiway and a fixed obstacle are required to be illuminated if the taxiway is used at night.

Objects which extend to a height of 110 m or more above ground elevation shall be referred to the Civil Aviation Safety Authority even if they do not impinge the clearance planes.

One or more obstacle lights shall be located at the top of the obstacle except in the case of a chimney or other structure of like function where the lights shall be spaced around the perimeter of that structure. Where the top of an object is more than 45 m above the level of the surrounding ground, additional lights shall be provided at intermediate levels. These intermediate lights shall be spaced as equally as practicable between the top light and ground level. Where low or medium intensity lights are used the spacing between the lights shall not exceed 45m. Where high intensity lights are used the spacing shall not exceed 105 m.

The number and arrangement of lights at each level to be marked shall be such that the object is indicated from every angle in azimuth. Where a light is shielded in any direction by an adjacent object, additional lights shall be provided on that object in such a way as to retain the general definition of the object to be lit. The shielded light may be omitted if, in the opinion of the flying surveyor (CASA) of the particular region, it does not contribute to the definition of the object to be lighted.
The top lights shall be so arranged as to at least indicate the points or edges of the object which is highest in relation to the obstacle limitation surface. In the case of a chimney or other structure of like function, the top lights shall be placed between 1.5 m and 3 m below the top. In case of a guyed tower or antenna where it is not possible to locate a high-intensity obstacle light on the top, such a light shall be located at the highest practicable point and a medium intensity obstacle light showing white, mounted on the top.

In the case of an extensive object or of a group of closely spaced objects, top lights shall be displayed at least on the points or edges of the objects highest in relation to the obstacle limitation surface, so as to indicate the general definition and extent of the objects. If two or more edges are of the same height, the edge nearest the landing area shall be marked.

Where low intensity lights are used they shall be spaced at intervals not to exceed 45 m. Where medium intensity lights are used they shall be spaced at intervals not to exceed 900 m. When the obstacle limitation surface concerned is sloping and the highest point above the obstacle limitation surface is not the highest point of the object, additional obstacle lights should be placed on the highest part of the object.

The lights shall be so placed that the obstacle can be readily identified (under normal visibility conditions) from a distance of at least eight kilometres and kept in view throughout the approach, landing and take-off manoeuvres. Under certain circumstances medium intensity lights may be required in lieu of a series of low intensity lights on an extensive obstacle.

An important point with low intensity obstacle lights is the type of light bulbs used. Under no circumstances should the compact fluorescent type of light bulb be used. These lamps do not have a filament focal point and therefore do not meet the requirements of the fresnel lenses used for obstacle lighting. The lens is designed to focus light at a set angle from the light fitting, this does not occur with the fluorescent light bulb. Newer models of low and medium intensity lights use red LEDs, and these are the obvious choice where long life is desirable from a maintenance point on difficult to access installations such as a radio mast etc. High intensity lights to date are usually a white xenon flash type.

For further information, see MOS-139 Chapter 9.4.

Permanent natural obstacles

Natural obstacles such as a line of hills requiring obstacle lighting are frequently so extensive that the fitting of lights as specified above for man-made obstacles would not be practical. There are many complexities associated with aircraft operations where such obstacles exist. Each case must therefore be considered separately on its merits and should be referred to the Civil Aviation Safety Authority for approval.

The general principle to be followed is where the position of the obstacle is such that aircraft are obliged to pass close to it, i.e. where it is located within the approach area, then the obstacle should be fully equipped with lights. Where the position of the obstacle is such that aircraft can carry out their approach, landing and take-off manoeuvre without approaching close to it, the lighting can be restricted to a small number of lights on the obstacle’s highest and most prominent features.
15. CONTROL AND MONITORING SYSTEMS

15.1 Airport requirements

Airfield Lighting requires some type of control and monitoring system. This ranges in scope and complexity, depending on the airport’s need. From a simple relay-based system costing in the order of thousands to a complex multi-PC-based system costing in the millions.

A common feature of all these controls, from simple to complex is they must be able to provide all MOS Part 139 requirements, and they should all operate in fail-safe mode. i.e. if any fault should occur in the system, then the system should go into default safe mode e.g. all lights on and twilight intensity selected. In addition, the controls should be secure. For example, it is possible today to control PLC or PC systems via remote login or control via personal smart device. While this may be desirable for the maintenance engineer to access and fix the system from home it raises the safety aspect that the login accessibility should be strictly controlled and managed.

**WARNING:** If this is not treated with care, it could be possible for an unauthorised person to switch off all lights remotely while an aircraft was on short final approach.

The main types of control systems in Australia, in order of installation numbers are:

1. **Basic**:
   - Relay based control.
   - Single or three stages of intensity.
   - Simple monitoring of basic parameters including operation, mains power availability, current selection as basics.
   - Usually incorporated into the same cubicle with the MIT(s), and PAALC unit. Often weatherproof and mounted outside.
   - Usually allows for off/local/remote control
     - **Off** when carrying out maintenance or not required
     - **Local** for manual selection
     - **Remote** which can include tower remote operation or auto PAALC control. For the latter this can be a set intensity or the intensity can be auto controlled for day/twilight/night by PE cells. Remote can also be operated from say the airport manager’s office or by airline representatives
   - Simple maintenance and fault finding.
   - Low cost.

The following may assist in selection of the best fit for your airport’s needs.
The circuit in Figure 15.1 shows a typical-three stage control utilising a MIT.

The MIT is labelled TX1 and it shows the primary winding connected to a three-phase supply via a mains contactor with its contacts controlling the primary winding of TX1.

The secondary windings of TX1 are connected to three contacts making selection for three intensity stages. These three contacts are controlled by the three contactors at the top of the drawing. The contactors are in turn controlled from the three stage DAY/TWILIGHT/NIGHT light-sensing circuit and its selections energise the appropriate contactor via an interlocking contacts set to ensure that only one intensity can be selected at a time.

When a change of intensity occurs, the old selection is turned off, the mains contactor is de-energised, the new selection of tapping is made, and the mains contactor is re-energised to power the circuit.

This arrangement forms an 'off load' tap-changing circuit so that only one intensity selection can be made and the high voltage secondary selections only change while the transformer is de-energised. In reality the MIT would have several other tappings as to allow adjustment of the voltage to achieve the desired output currents.
**Figure 15.2:** Example of an intermediate PLC based control system

<table>
<thead>
<tr>
<th>1</th>
<th>Logical cabinet with:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• PLC rack</td>
</tr>
<tr>
<td></td>
<td>• 24V DC UPS device</td>
</tr>
<tr>
<td></td>
<td>• Ethernet switch</td>
</tr>
</tbody>
</table>

| 2 | Touchscreen control panel with Ethernet connection and USB-memory |

| 3 | Maintenance PC with 21.5” screen, HP PC / Win OS, control, monitoring and configuration interface software, Ethernet link, UPS and printer |

<table>
<thead>
<tr>
<th>4</th>
<th>Station cabinets with:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• 14 auxiliary channel connection</td>
</tr>
<tr>
<td></td>
<td>• 24V DC UPS</td>
</tr>
<tr>
<td></td>
<td>• Ethernet switches.</td>
</tr>
</tbody>
</table>

| 5 | Standard Ethernet cable RJ-45 connector |

| 6 | 24V DC power cable |

| 7 | Optical Ethernet cable (Not included in the system) |

| 8 | IDM 8000-SM CCRs (must be ordered separately) with serial Modbus TCP connection. Other CCRs and devices may be connected with Modbus TCP RIO (remote input/output) units |

**2 Intermediate:**

» PLC-based control.

» Up to six stages of intensity.

» More features available than relay logic systems e.g. can monitor down to component level such as CCR fault types, hours run, circuit faults, individual circuit components to name a few.

» Usually incorporated into a rack mounting or cubicle installed inside the ALER.

» Can control multiple circuits, CCRs, runway and taxiway selection, PAPI etc. genset/mains parameters etc.

» OFF/LOCAL/REMOTE control is normal.

» Potentially more complex maintenance if a fault occurs but this is partly offset by self diagnosis features.

» Cost is coming down to be comparable to more complex relay-based systems.

**3 Complex:**

» PC-based control.

» More common for larger international airports where individual lamp control and monitoring is desired.

» Able to do everything a PLC-based system can.

» More complex user interfaces e.g. for tower or ALER are common.

» Can incorporate individual fixture control and monitoring.

» Deeper level of fault diagnostics typically provided.

» Typically provided in redundant architecture but not always e.g. a complex airport may have two x PCs in the tower cab, two in each of the ALERs making a network of 10 or more PLCs providing multiple redundancies.
Figure 15.3: Example of CAT II/III control and monitoring system
15.2 Intensity settings

For six-stage intensity systems, the rule of thumb is that if Stage 6 = 100%, then divide each level by one-third, e.g.

<table>
<thead>
<tr>
<th>STAGE</th>
<th>% INTENSITY</th>
<th>TYPICAL CURRENT SETTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>100%</td>
<td>6.6 A</td>
</tr>
<tr>
<td>5</td>
<td>33%</td>
<td>5.5 A</td>
</tr>
<tr>
<td>4</td>
<td>11%</td>
<td>4.8 A</td>
</tr>
<tr>
<td>3</td>
<td>3%</td>
<td>3.8 A</td>
</tr>
<tr>
<td>2</td>
<td>1%</td>
<td>3.4 A</td>
</tr>
<tr>
<td>1</td>
<td>0.3%</td>
<td>3.0 A</td>
</tr>
</tbody>
</table>

This will vary slightly depending on facility and is usually fine tuned during flight testing.

For three-stage intensity systems, the rule of thumb is to use the equivalent of Stages 2, 4 and 6 above, e.g.

<table>
<thead>
<tr>
<th>STAGE</th>
<th>% INTENSITY</th>
<th>TYPICAL CURRENT SETTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>100%</td>
<td>6.6 A</td>
</tr>
<tr>
<td>2</td>
<td>11%</td>
<td>5.5 A</td>
</tr>
<tr>
<td>1</td>
<td>1%</td>
<td>4.8 A</td>
</tr>
</tbody>
</table>

For single-stage intensity systems, the current requirements to meet the specification is 100 per cent of 6.6 A. However, note that lower wattage lamps are used; e.g. typically for the runway edge lighting 30 W for a single intensity system, 45 W for a three-stage system, and 150 W for a six-stage system.

Additionally, this current may be adjusted during flight testing as deemed suitable for that location.
16. PILOT-ACTIVATED AIRPORT LIGHTING CONTROLLER (PAALC) AND AERODROME FREQUENCY RESPONSE UNIT (AFRU)

16.1 System overview

The PAALC and AFRU can be stand-alone units or in some cases may be a combined unit incorporating both systems.

For a standalone unit, a PAALC will have its own dedicated frequency allocated through application to AsA, while the AFRU will be on the existing CTAF or MBZ frequency of the airport.

Combined PAALC/AFRU units will always operate on the existing CTAF or MBZ frequency of the airport. This frequency will be published in the ERSA.

In either case both the PAALC and AFRU must meet the requirements of MOS Part 139 Chapter 9.3 to operate as either a pilot activated airfield lighting control (PAALC) or an aerodrome frequency response unit (AFRU), or both functions at the same time.

Pilot-activated airfield lighting control (PAALC)

The pilot activated airfield lighting control unit allows the pilot to select the airfield ON lighting using the communications radio in the aircraft.

When the radio is set to the PAALC frequency, the airfield lighting can be selected by three carrier transmissions i.e. the pilot presses the microphone transmit button three times. The correct code is to consist of three bursts of carrier signal each anywhere between one and five seconds long, with the last two code bursts completed within 24 seconds of the end of the first burst. The ERSA advises pilots that “the code they should send is three bursts of approximately 3 seconds, with at least 1 second between bursts, and the three bursts must be transmitted within 25 seconds”.

A correct code will be recognised by the control unit as a light ‘ON’ command. When the lights are selected, they will remain on for a predetermined period set during the PAALC setup procedure of between 30 minutes and 90 minutes.

All units should be configured to be fail-safe so that failure of the equipment will result in the lights being turned on.

The PAALC in recent cases will transmit a voice message of the status of the lights.

These messages can be:
» NO runway lighting.
» Runway lighting ON.
» Lights 10 minutes remaining.

Automatic frequency response unit

When configured as an AFRU, the equipment will monitor the selected CTAF or MBZ frequency for transmissions.

An aircraft making the required transmission of the aircraft’s identification and location when entering an aerodrome locality will constitute a transmission greater than two seconds in length. The equipment on receiving this transmission will recognise it and respond on the common air traffic frequency (CTAF) with a transmission of the airport name e.g. Lilydale CTAF.

This will confirm to the pilot that the radio is working and is on the correct frequency. It will also notify other aircraft in the area of the presence of another aircraft. The constant repeat transmission by the AFRU when aircraft may be engaged in a conversation would be a distraction so after one operation of the AFRU message, a timer is set for a period of five minutes so that subsequent transmissions that would trigger the AFRU will cause it to transmit a 300 mS BEEP, hence the generic name for this type of equipment as ‘beep back’.
**Combined PAALC and AFRU systems**

Where the PAALC and AFRU are in the one unit the sequence for selecting the PAALC is different to that required for a stand-alone PAALC.

The required sequence is detailed in the ERSA notes.

**16.2 Maintenance**

Due to the different types of units on the market, you should ensure you have a copy of the relevant manufacturer’s handbook for your equipment on hand to cover basic troubleshooting. Note that for the most part the most common reported faults lead back to operator error with respect to transmission and timing of the three pulses. Ensure that this is first tested to be working correctly before pursuing other possible faults. Other than faults, the only real maintenance is the replacement of the internal battery as per the manufacturer’s recommendations.
17. POWER SUPPLY FOR AFL SYSTEMS

A reliable power supply is paramount when operating an AFL system.

Depending on location and size of the airport, the AFL system may operate on a mains supply or a power generator.

A useful document in designing this is the ICAO Aerodrome Design Manual Part 5. If carrying out any new works, it is suggested reading this first, and if considered necessary, employ a suitably experienced consultant to assist with design.

17.1 Mains supply

For the majority of regional airports in Australia this is a reliable supply authority mains supply or in remote locations a primary generator supply is sufficient for powering the needs of basic AFL systems to meet MOS Part 139 requirements.

Care should be taken to ensure that the supply feeders are close to where you need them and that they are secure and reliable. If they need to be extended to site, be aware of the costs involved, including substation costs as well as overhead or underground mains.

Once the airport is rated for CAT I to CAT III power supply requirements become more demanding in that a secondary source of power is required. As an example, this can be achieved by providing feeders from separate transmission lines, fed by separate generators, fed to separate substations or a ring main system. It is not intended to cover this in depth here, and as can be appreciated it is not usually available outside larger cities.

17.2 Standby power

While licensed regional airports are not always equipped with standby power this changes again once aerodromes become rated to CAT I and above. For these airports, automatic changeover switching to standby power is required in the case of a primary failure.

The changeover time requirements vary depending on the facility. However, in simple terms at CAT I, AFL load needs to be able to switch to backup power within 15 seconds. This can be achieved by selecting an appropriately rated rapid start diesel generator.

Most modern units can be supplied with all necessary automatic engine controls and changeover switches. When selecting a suitable generator rating, note it is necessary to balance desired additional capacity for future expansion, against generator efficiency and suitable long term operations (e.g. diesel engines do not perform well over time where the connected load is low, they like to run at close to full rated load).

For CAT II or III, the changeover time goes down to one second. There are different ways to achieve this. Firstly, if a satisfactory independent primary supply is available. However, this is rare. Second and most commonly, is to start a standby diesel generator as soon as the RVR is in the order of 1200 m, and then run the AFL load on the generator with the automatic transfer to primary supply in case the secondary supply (the generator) fails. This will enable the required one second changeover to be achieved. The critical load should remain on the generator until an RVR of greater that 1200 m is regained.

Other standby power solutions involve very large battery bank UPS or standby fly wheel driver generators. These are not covered in this particular note as they are not common on regional airports for AFL loads at present.
18. PORTABLE AND TEMPORARY LIGHTS

For permitted applications refer MOS Part 139 Chapter 9.1.10.

In the past, these types of lights were mainly restricted to emergency use or temporary replacement of failed fixed lights.

In recent years with the continued development of solar battery-powered LED lights, we are starting to see higher power units that are comparable in output to fixed permanent taxiway lights. In time, low intensity runway applications for permanent installation may follow and eventually achieve intensities comparable to low intensity fixed permanent lighting systems.

18.1 Types of portable lights

There are four main types of portable or temporary lights in use in Australia:
» older kerosene flares, also known as Toledo Flares;
» dry cell, disposable battery, filament lamp flares;
» rechargeable battery flares, in filament or LED versions; and
» solar powered, rechargeable battery LED flares.

The latter are the easiest to use as no daily maintenance is required. However, as usual, cost can be a consideration.

These lights may be considered, subject to compliance issues, for use as temporary taxiway or runway edge lights during construction periods. If in doubt, refer to your local CASA inspector.

If these lights are regularly used as temporary edge lights, it may also be worth considering laying out marker pads to sit them on, so as to speed up efficient and accurate dispersal when needed. e.g. in an emergency situation.
19. SERVICEABILITY

Please refer to MOS Part 139 Chapter 9.20 for monitoring, maintenance and serviceability requirements.

19.1 Record Keeping

Serviceability records are most important and the medium in which serviceability records are stored can determine their usefulness. Records that are difficult to locate or interpret lose their value as a maintenance tool. To keep effective track of an airfield lighting system’s serviceability requires a method that can easily identify lights and their position in the system, a detailed record of all maintenance performed on the individual light and a record of all components replaced.

19.2 Commissioning records

These records must be included in aerodrome manuals. Ongoing proof of compliance may include regular serviceability audits against commissioning records to demonstrate continuing compliance e.g., apron floodlighting levels. MOS-139 Chapter 21, Part 6 contains some typical examples that can be used for commissioning or regular maintenance checks.

19.3 Lamp position identification

The numbering of light positions is the most effective method of identifying individual lights in the field situation. Although on a major airport this is a large project, once completed it makes the record-keeping of the individual light position a very precise maintenance record. As light positions are numbered around the system it only requires the runway or taxiway identification to be included in the record keeping form to obtain a complete picture of the maintenance status of a system.

19.4 Information recording and storage

Information is generally gathered on a printed form that has been designed for a particular system and is entered in routine maintenance checks of the system. If a light position requires attention, the type of work performed and the use of any components can be entered on the recording form. The information collected on these forms can readily be entered into a spreadsheet to constantly update the number of lamps used etc. during a set period. This makes retrieval of the stored information easy and staff can quickly assess any potential problem areas in the system.

19.5 Maintenance and record keeping

From the maintenance record of a light or several light positions, potential faults or problems can be detected. If a light position is using an abnormally high number of lamps over a period, it may be that there is a fault with either the lamp assembly itself or the SIT associated with that light. From these records the lamp life of a particular batch of lamps may be determined and if they are not meeting the suppliers stated lamp life then the airport can investigate any circumstances on the airport causing this, or report to the supplier. Every time work has to be performed on a light unit it costs money. Careful monitoring of maintenance records can detect problems, which ultimately will save money in time and materials.

19.6 Effective staff training and participation

A serviceability record-keeping system is only as good as the staff who are entering the information into the system. If the staff do not enter the correct details, then the system is doomed to failure. If staff are fully informed of why the information is required and the importance of accurate information being recorded, then the system should prove to be effective.

It has to be stressed that the record keeping of the maintenance details is as important as the changing of lamps and the maintenance of the light unit.
19.7 Serviceability records

Each airport will have to design the system for recording their serviceability around the operational system for their individual airport.

Experience has shown that the simpler and easier a form is made the more likely staff are to complete the form accurately, therefore ensuring useful data can be accessed when determining maintenance procedures and forecasting component purchase.

Under the case studies (Chapter 21) there are two examples of inspection checklists.

19.8 Serviceability standards

If any of the following details applies to your lighting system, then they will be deemed unserviceable.

Your CASA inspector should be contacted if you are unsure of the serviceability of your system.

» In the case of any lighting system comprising less than four lights (e.g. short taxiway holding position lights or runway threshold identification lights), if any one of the lights becomes unserviceable.

» In the case of any lighting system comprising four or five lights (e.g. wind direction indicator lights or runway guard lights), more than one light becomes unserviceable.

» In the case of a lighting system comprising 6 to 13 lights (e.g. threshold lights), more than two lights become unserviceable, or two adjacent lights becomes unserviceable.

» In the case of a lighting system comprising more than 13 lights, more than 15 per cent of the lights become unserviceable, or two adjacent lights becomes unserviceable.

» Any one low intensity (fixed red light) obstacle light is extinguished (Note: this is two lamps in a dual fitting).

» Any one medium intensity (flashing red light) is not operating normally.

» Below 85 per cent of approach lighting is working as a recognised pattern.

» A PAPI light unit (i.e. a single box) is deemed unserviceable when any one lamp in a two lamp box, or more than one lamp in a three lamp box is not operating.

» A single-sided PAPI system (i.e. four light boxes) is deemed unserviceable when any PAPI light box is unserviceable as above.

» A double-sided PAPI system (i.e. eight light boxes) is deemed unserviceable when any PAPI light box is unserviceable as above.

» If any PAPI red filter is unserviceable, missing, damaged then all lights within the light unit is to be extinguished until the filter is replaced. This would render any PAPI light unit (and therefore any PAPI system unserviceable.

For Category I and above precision systems refer to MOS-139 Chapter 9.20.
20. SAFETY AND BEST PRACTICES

20.1 Safety considerations

This section contains information that will aid airport staff to conduct safe work practices.

Safety is the responsibility of each individual, regardless of position. Safety must be practised daily in every maintenance activity that is performed.

The safety program established at each airport should include preventive safety precautions used when servicing the equipment as well as first-aid procedures for use in the event of an injury.

WARNING: Only suitably qualified staff should be permitted to work on AFL electrical systems.

Common causes of accidents

Some common causes of accidents are listed below.

» Working on equipment without adequate coordination with equipment users.
» Working on equipment without sufficient experience on that equipment.
» Failure to follow instructions in equipment manuals.
» Failure to follow safety precautions.
» Failure to properly lock out equipment.
» Using unsafe equipment.
» Becoming lax due to working in a familiar environment.
» Poor housekeeping of work areas.
» Working at unsafe speeds.

The number one cause of accidents is working at unsafe speeds. This is often the main contributing factor in failing to follow proper safety guidelines in all the other causes outlined in the list above. The perception that there is not enough time to take proper safety precautions or think through the proper procedures has the potential for causing an accident. Even in emergency repair situations, care must be taken to make the time to follow proper safety procedures to avoid injury or death.

Safety procedures and guidelines

Most visual aids are exposed to weather and moisture and may develop electrical shock hazards through damage from lightning or insulation deterioration from exposure.

Begin maintenance procedures only after a visual inspection has been made for possible hazards.

Due to the danger of lightning, lighted navigational aids should not be serviced during periods of local thunderstorm activity.

Develop and implement a set of action plans to follow in the event of an accident occurring.

Ensure that positive responsive actions take place within moments of accident notification by establishing and having in place a known set of predetermined responses. Precious seconds are saved getting medical assistance to those in need when action plans are in place. Rehearse and review action plans regularly.

Electrical hazards of series lighting circuits

Airport lighting circuits, by their nature, are very dangerous.

This is especially true for the uninformed electrician with little or no experience working on constant current series circuits.

Airport lighting circuits can operate at potentials of several thousand volts depending on the size of the regulator driving the circuit and the load.

There are three basic rules to remember when working on and around airport lighting circuits:

1. **ALWAYS** assume that the circuit is energised until you have proven otherwise. **ALWAYS** check for current before disconnecting the series circuit connector, removing a series cut-out plug, or opening the primary series circuit by any other means. Make it a required practice to check the circuit with an ammeter prior to breaking the connection – **NO EXCEPTIONS**. Never attempt to measure voltage in a series lighting circuit using ordinary volt meters. An inductive voltage measuring device (sometimes referred to as a ‘ticker’) should be used to detect the presence of induced voltage on a series lighting cable after checking for the presence of current.
Always use a true RMS clamp-on type ammeter to verify if the circuit is energised. **ALWAYS** check the operation of the test equipment on a known live circuit before and after measurements are taken.

2 **NEVER** under any circumstances break a live series circuit. The voltage generated in the circuit can reach levels many times normal before the regulator’s open circuit protection can shut it down. As long as a current flow can be maintained, even if it is through you, the regulator will continue to operate. This is one of the reasons that series circuits can be so hazardous to work around. By their nature, there is no personnel protection provided such as might be found on parallel interior wiring.

3 **NEVER** enter a manhole with energised conductors and never handle cables or transformers in light base housings while there is current present. Cables or connectors can have cracked insulation where it is not visible or may be deteriorated and fall apart, exposing you to circuit conductors. Be aware that water in pits increases the dangers of electric shock because of the possibility of circuit leakages to earth or cable faults due to the increased conductivity when a person makes contact with the water.

### 20.2 Induced voltages.

Series circuits are typically run from the AFL equipment room or cubicle in duct banks where the wires are lying parallel with each other in close proximity.

Voltages may be induced in an otherwise un-energised conductor and may be a hazard when troubleshooting and testing. Circuits that have a load that varies due to flashing action of runway guard lights or strobes are particularly prone to induce voltages in other conductors due to the pulsing characteristics of the voltage and current in these circuits.

Always check for induced voltages before handling an airfield lighting series circuit conductor.

### Re-lamping

The most common lighting maintenance task on the airfield is re-lamping of runway and taxiway light fixtures.

On larger airports this is carried out by licensed electricians. For smaller airports this task is often performed by maintenance staff or airport reporting officers (AROs). Under no circumstances should the latter staff work on ‘live’ circuits. Safe re-lamping instructions should be included in airport procedure documentation and staff provided with copies.

Depending on the type of fixture, this may be accomplished in the field or, as in the case of most inset lights, the entire fixture is removed, replaced, and brought to the maintenance shop for refurbishing.

The greatest unseen danger to you is re-lamping or removing the fixture when the circuit is energised. This has been a common practice by airport electricians for convenience and the dangers are often overlooked.

There are two primary hazards associated with this practice.

The first occurs when a series isolation transformer has a primary to secondary short in the windings. Remember that even though these are referred to as isolation transformers, they were not designed for personnel protection. They are merely designed to isolate the secondary from the primary circuit to allow the circuit to continue to operate with a lamp burned out. While the series isolating transformers are reliable, failures do occur. A transformer with a primary to secondary short may not cause a circuit malfunction and could therefore remain unnoticed in normal operation with a live primary. This exposes you to the full voltage present on the primary circuit and can be especially dangerous if another short is present on the primary circuit. When that happens, you can become the path to ground for the full primary current, a circumstance which is almost always fatal. This condition is especially dangerous when working with inset lights and removing them from the light base can while the circuit is energised.
As soon as the fixture is unbolted and lifted from its housing, you become the path to ground. Some have tried to alleviate this hazard by attaching a ground wire from the bottom of the light fixture to a grounding lug on the inside of the can. However, you cannot know if the wire is truly connected until you remove the fixture, at which time it is too late.

The second hazard encountered when re-lamping an energised light fixture is from the open circuit voltage present at the secondary of the transformer. The open circuit voltage present on the secondary of the transformer is proportional to the size of the transformer. The open-circuit secondary voltage on a 300 watt transformer is approximately 110 volts. Moreover, depending on the materials used in the design of the isolation transformer and the type of regulator powering the circuit, relatively high voltage peaks can be generated. The larger the transformer, the higher the peaks. With as much as 200 volts being generated in some circumstances. The duration of this peak varies inversely with the size of the transformer (i.e. larger transformers have shorter durative spikes). Because of their size and duration, the peak voltages can create an unsafe condition for maintenance personnel. Therefore, we recommend that you perform re-lamping of the series lighting circuits with the circuits de-energised, especially during the re-lamping of fixtures with exposed contacts. If this is not practical, wear appropriate insulating gloves with leather gauntlets during re-lamping procedures.

One final hazard that is present when re-lamping any type of fixture, whether in the field or at the maintenance shop, is the danger of cuts from broken lamps. Many times when an airfield lamp fails, the glass envelope becomes cracked or brittle and can break during the removal process. Always wear leather gloves when removing lamps to prevent your hands from being cut in the event of a lamp shattering.

20.3 Safety practices
When you perform maintenance on airport visual aids, use the following safety practices.

1. Ensure that workers are trained and familiar with electrical safety.
2. Strictly observe safety rules.
3. Ensure that commercial test equipment is Underwriters Laboratory (UL) approved and rated for the voltage under test and/or for the application.
4. Prior to beginning any maintenance work on airport lighting circuits, coordinate the work schedule with the tower, facility manager, or airport operations personnel. Make sure circuits will not be energised during maintenance by observing strict lock-out tag-out procedures for the equipment and obtain authorisation for local control if equipment is normally operated from a remote control point.
5. Where maintenance work is to be accomplished on a high-voltage circuit, assign at least two electricians, with at least one having a thorough knowledge of the layout of all airport high-voltage circuits.
6. Because performing maintenance on many lighted visual aids requires workers to traverse the active airfield, all workers shall be fully knowledgeable of air traffic control and radio communication procedures. Workers shall be fully familiar with airport runway and taxiway layout to avoid any possibility of runway incursions. All air traffic control instructions shall be read back to the controller and if the worker has any question regarding the instructions of the controller, the worker shall ask the controller to repeat the message.

If you are the observer electrician, you have a number of duties.

» Keeping other personnel not involved in the work clear of the equipment.
» Being familiar with power disconnects and immediately disconnecting the power source in case of emergency.
» Being qualified in first-aid and prepared to render emergency care if necessary. You should bear in mind that prevention of an electrical accident is of primary importance even though first-aid treatment is available.
» Observing the work being done to detect and warn against unsafe practices.
20.4 Personal safety precautions

Every electrician should adopt the following commonsense safety precautions as standard procedure.

» Know the location of main power disconnect devices.

» Know how to summon medical aid.

» De-energise circuits by removing necessary fuses using properly insulated fuse pullers or by turning off and locking out circuit breakers or other disconnecting means. Consult circuit diagrams to identify all fuses, breakers or disconnects involved. Remember that removal of a fuse does not remove the voltage from the 'hot' side of the fuse clip. Discharge all capacitors.

» Do not depend on interlocks to remove power or on indicating lights to signal that power is off. Verify that power is off by using a voltmeter and/or ammeter on the component after opening the power switch. Verify operation of voltmeter (or ammeter) on known live circuit before and after measurements are taken.

» Insulate your feet by standing on a dry rubber mat. Remember, however, that contact with the grounded equipment cabinet could nullify this protection.

» Stay clear of terminals, leads, or components that carry voltages of any magnitude. Also, avoid contact with components that are grounded, including the frame.

» Shut down and de-energise the equipment when it is necessary to reach into the equipment in locations where rapid and direct withdrawal of the hand is not possible. In any case, only one hand should be exposed, with the other hand kept away from contact with voltages or ground.

» Be certain that there is no power applied to a circuit when making a continuity or resistance check (the meter will be damaged and you could be injured).

» Ground test equipment to the equipment under test unless otherwise specified in instruction manuals.

» Place a warning sign, such as ‘DANGER - DO NOT USE OR OPERATE’, at the main switch or circuit breaker, and provide a lockout for the circuit on which you will be working. Follow direction of local facility lock-out tag-out procedures manual.

» Do not wear jewellery, wristwatches, or rings while working with electrical equipment.

» Keep clothing, hands, and feet dry if at all possible.

» Use the correct tool (screwdriver, alignment tool, etc.) for doing the job. Ensure that the tools are in good serviceable condition.

» Never use toxic or flammable solvents for cleaning purposes.

» Where air pressure is required for cleaning, use a low-pressure (30 psi or less) air source. Eye protection (goggles or face mask) is necessary when using compressed air for cleaning.

» Wear goggles and safety shoes when working near or around high voltage.

» Do not take anything for granted when working with inexperienced help.

20.5 Electrocution

An electric shock is the passing of an electric current through a person. The amount of damage to the person depends on the amount of voltage and current to which the person is subjected.

Voltages between 200 and 1,000 volts at commercial power line frequencies are particularly harmful since, under these conditions, heart muscle spasm and paralysis of the respiratory centre occur in combination. However, lower voltages can also prove fatal, as evidenced by records of deaths caused by 32-volt farm lighting systems. The body response to current is as follows:

» 5 to 15 mA stimulates the muscles

» 15 to 19 mA can paralyse the muscles and nerves through which it flows

» 25 mA and above may produce permanent damage to nerve tissues and blood vessels

» 70 mA and above may be fatal.

The injurious effects suffered during electric shock depend upon the path of the current through the body. The current path will take the most direct route through the body from the two points of contact. For this reason, any current path which involves the heart or the brain is particularly dangerous. Therefore, keeping one hand clear of the equipment will eliminate the possibility of a current path from arm to arm.
Permanently place ‘DANGER – HIGH VOLTAGE’ signs on all fixed electrical equipment where potentials of 500 volts or more terminal-to-ground are exposed. Place signs in a conspicuous location, usually on the outside of the equipment.

**Lock-out/tag-out and danger tags**

Each airport electrical maintenance department should have a written lock-out/tag-out procedure. Equipment or circuits should never be worked on unless locked out and tagged by the person performing the work. Never trust anyone but yourself. Have your partner check behind you to make sure the proper equipment is turned off. The lock-out tag should only be removed by the person who signed it except in some circumstances when verbal permission has been granted to another person or when the worker who signed the tag is on vacation, etc. Never rely on the tower controllers to assure electrical safety. The controllers in the tower are relieved periodically and the next person may not know of the work that is going on. Always take whatever time is necessary to make sure that the circuit or equipment you are working on is safe. One of the primary reasons for accidents is when workers get in too great a hurry and don’t take proper precautions and don’t follow proper safety procedures. The other main reason is when the electrician lets his/her guard down because he/she is working in a familiar environment and becomes negligent about safety procedures.

**Locks and padlocks**

Use built-in locks on switch gear and disconnecting switches whenever the equipment is tagged, and, on completion, return the keys to the supervisor responsible for their control. Padlocks need not be used if it is decided that use and control of such locks would be difficult because of the type of switchgear and its location. However, use padlocks with ‘DANGER’ tags when equipment or electrical lines remain out of service or when electrical work has been discontinued until a later date. When outside contractors are involved, each contractor should attach and control tags and locks independently.
Figure 20.3: First Aid Treatment for Electric Shock.
Grounding and Bonding

Never remove, alter, or attempt to repair conductors or conduit systems providing grounding or electrical bonding for any electrical equipment until all power is removed from equipment. Warn all personnel of the ungrounded/un-bonded condition of the equipment. Display appropriate warning signs, such as danger tags, to warn personnel of the possible hazards.

It is also very important to ensure that all safety earths are removed when the work is complete and is ready to be re-energised.

20.6 Test equipment

Suggested test equipment includes:

» multimeter, true RMS, minimum 10 A scale;
» insulation tester, ‘megger’ or similar, minimum 1000 V test voltage;
» ammeter, clamp type, true RMS, minimum 10 A;
» cable locator;
» light meter, 0-100,000 Lux (must be suitable for the type of lights being measured); and
» luminaire levelling and alignment tools to suit your installation.
21 CASE STUDIES

1. SAMPLE RUNWAY LAYOUT DESIGN ESTIMATES
2. SAMPLE MAXIMUM POWER REQUIREMENT ESTIMATE
3. LED VS HALOGEN LAMP COMPARISON COST ESTIMATE
4. AFL CABLING SYSTEMS – STANDARDS COMPLIANCE FOR DEPTH OF CABLE
5. SERVICEABILITY CHECKLIST
   A) BASIC AIRPORT
   B) INTERMEDIATE AIRPORT
6. COMMISSIONING CHECKLIST
   A) AIRFIELD LIGHTING
   B) PAPI
   C) APRON FLOODLIGHTING
CS1. SAMPLE RUNWAY LAYOUT DESIGN ESTIMATES

1.1 Example of estimate for quantity of materials

For this example, we have assumed: runway length 1240 metres, runway width 30 metres.

1 x single taxiway 300 metres in length, 1 x single circuit of primary cable.

1.2 Calculations for quantities of materials

Runway edge/threshold/runway End

Runway length 1240 m / 60 m (maximum spacing) = 20.66 then rounded up to 21 spaces 21 spaces = 22 light positions with the positions at each end being green/red threshold white edge lights 20 per side spaced 59.04 metres apart = 40 lights.

Green outer threshold lights = 2 per threshold (total 4).

Red/green combined threshold/runway end lights = 6 per end (total 12).

Taxiway/holding position (elevated edge) Yellow Holding Point Lights = 2 per taxiway

Blue taxiway lights – plans are required to determine exact quantities of taxiway lights as this can depend on the radius of curves as to the spacing. For the purposes of a small airport with a short taxiway leading directly to the apron generally speaking the quantity ranges from 12-20. Full details of what spacing is required can be found in MOS-139 Chapter 9.13.14 and an estimation of the quantity for budgetary purposes can be made. For this example, we have assumed maximum 20 blue taxiway lights.

Series isolating transformers

One required for each light fitting.

Primary cable

» Runway length 1240 x 2 = 1480 m + length to where the cables cross the runway (say 60 m per end = 240 m) giving a total of 1720 m.

» Runway width 30 m x 2 = 60 m + distance to out to where the cables are run (say 6 m off the runway edge = 24 m) giving a total of 84 m.

» Allow 2 metres minimum extra per light position – in this case 78 lights x 2 metres = 156 metres.

» Taxiway length x 2 = 600.

» Cable from taxiway to control unit x 2 – in this case we have assumed this to be 600 metres.

» Subtotal cable = 4,360 metres, rounded to 4500 metres.

» Allow a minimum of 10 per cent (or in this case smallest cable drum size of 500 m) as in practice there is some wastage due to offcuts or short lengths and final cable route can change.

» TOTAL allow 6,000 metres primary cable.

Secondary Cable

Secondary cable is only required where the factory-fitted tails on the series isolating transformers are not sufficient to reach to the light fitting or the primary cable respectively. In this case we have assumed the primary cable and SITs are 6 m off the runway edge. The lights will be approximately 1 m off the runway and taxiway edge giving a 5 m secondary cable length. Allow 2 m each end gives 9 m per light.

TOTAL allow 750 m Secondary Cable.
Cable jointing kits or connectors

Each primary cable join in the primary cable run requires 1 x primary heat shrink jointing kit or 1 primary connector kit.

Each series isolating transformer requires 2 x primary heat shrink jointing kits or a connector kits for both primary in and out connections (dependent on the style of SIT used i.e. Australian style epoxy transformer or FAA style transformer). Allow 80 primary jointing kits. Each light position requires a secondary connection to the series isolating transformer which can be a secondary cable heat shrink kit or an FAA-style connector (again depending on the style of transformer used). Allow 75 secondary jointing kits.

Control system

1 x PAALC/AFRU combined unit.

1 x waterproof outdoor airport lighting control cubicle (including control equipment).

1 x mains isolating transformer (appropriately sized as below).

Mains isolating transformer sizing

See Case Study 3.

Illuminated wind direction indicator

1 per airport in the majority of instances.

Note: With the illumination requirements for the IWIs, these are now generally achieved using a 240 V system and LED floodlights. You should allow adequately sized mains power cable to the IWI from the mains power source.

Apron floodlighting

Any local lighting company will offer a lighting design to ascertain the quantity of lights and poles required. Ensure that they are familiar with the relevant MOS-139 requirements as contained in Section 9.16.

1.3 Cost estimates

This example is typical only and must be used carefully. This is in no way intended to be a total final figure for each airport. It should form the basis of a ‘budgetary quote’ only based on the requirements for the particular airport using the prices that are current prices at the time. Note this does not include costs associated with any civil works such as trenching, backfill, excavation, concrete foundations etc. As these vary considerably due to local soil conditions, the presence of rock etc. this should be sought as a separate figure to include into any estimate.

Elevated light - allow $1,500 each installed (includes supply of light, series isolating transformer, connectors or heat shrink, simple plastic pit and installation).

Inset light - allow $2,500 each installed (this includes supply of light and base, series isolating transformer, connectors or heat shrink, simple plastic pit and installation).

Primary cable - cost of materials (around $3 to $4) + $3 a metre to lay cables. (As stated above please remember to allow additional cost of civil works such as trenching, backfill etc.).

Control cubicle - weatherproof, outdoor, lockable cubicle including PAALC and MIT. Allow up to $25,000 plus civil works for concrete foundation plus cost of bringing any mains power supply to site.

Illuminated wind direction indicator - allow cost of IWI plus the cost of any mains power cable (will need to be sized and costed dependent upon the length of the cable run), trenching, backfill etc.

Apron floodlighting - allow cost of any poles and lights plus the cost of any mains power cable (will need to be sized and costed dependent upon the length of the cable run), trenching, backfill etc. Any major lighting company should be able to provide design of the apron floodlighting including height and configuration of any poles.
CS2. HOW TO ESTIMATE THE POWER NEEDS OF AN AFL SYSTEM

First we need to make a few assumptions for this exercise.

» Three stages of lighting intensity
» one 6.6 A circuit for the combined R/W and T/W load.
» one 6.6A circuit for the PAPI
» runway of 1240 m
  – 40 R/W lights at 45 W each
  – 4 Outer T/H at 150 W each
  – 12 T/H lights at 45 W each
» short 200 m stub taxiway to apron
  – 20 T/W lights at 30 W each
» PAPI on both ends
  – 8 units of 2 * 200 W lamps = 400 W each
» two floodlight poles
  – 4 * 400 W

From experience we can assume the following losses.
» MIT has 0.8 PF
» SIT losses are also 10 per cent
» primary cable losses are 145 W/km
» secondary cables are 327 W/km.

Calculation of R/W and T/W MIT load then is:

R/W + T/H + T/W = (40*45)+(4*150)+(12*45)+(20*30) = 1800 + 600 + 540 + 600 = 3,540 W lamp load.

SIT losses bring this up to = 3,540 * 1.1 = 3,894 W

Primary cable losses for

R/W and T/W circuit = 1.96 km R/W * 2 sides + estimated 1,200 m for T/W and Apron + 1,200 m for the run to the cubicle = 4,360 m. Say 4.5 km.

4.5 Km * 145 W cable losses = 653 W losses.

Secondary cable losses for

R/W and T/W circuit = 0.75 km

0.75 km * 327 W cable losses = 245 W losses.

So total power needs for the R/W, T/H and T/W are

3894 + 653 + 245 = 4,792 W.

Assume PF of 0.8 for the MIT (or CCR) so rating needs to be 4,792/0.8 = 5,990 VA or 5.99 kVA.

Then select closest standard size MIT which is 6 kVA. (Or say 7.5 kVA for a CCR).

Similarly, for PAPI circuit we have 8 units of 400 W = 3,200 W *1.1 SIT losses = 3,520 W.

Primary circuit length estimate of 4.5 km, so losses of 145 W * 4.5 = 652 W 3520 + 652 = 4,172 W.

Assume PF of 0.8 so total load is 4,172/0.8 = 5,215 VA or 5.215 kVA Then select closest standard size MIT of 5.5 kVA. (Or 7.5 kVA for a CCR). Note: Standard size MIT or CCR details are available from your vendors.

Similarly, again, to calculate the losses for the IWI and the apron floodlights, this will be a function of cable length to each mast from the switchboard and cable size. This can be easily calculated by any local electrician.

So the AFL control cubicle will contain the switchboard, the three stage controls, the PAALC, the MIT for the R/W and T/W circuit, plus an MIT for the PAPI.

The circuits will include as a min:

1 * 6.6 A for the R/W and T/W
1 * 6.6 A for the PAPI
1 * 240 V for the IWI
2 * 240 V or 1 * 240/415 V 3 phase for the floodlights.
CS3. LED VERSUS LAMP COST ESTIMATES

You can ask your vendors to provide some comparison costs. The main consideration will be initial capital costs versus through-life costs. If the future savings are good enough, then the LED system may pay for itself over time with reduced power needs, less maintenance, and CO2 costs if they are a consideration.

The AAA has a sample calculator which can be found on the website. You will need to input your own particulars and the calculator will then estimate relative costs of LED versus halogen and the applicable payback period. An example is shown in the following table.

<table>
<thead>
<tr>
<th>eg. Cat 2 Taxiway: AAA AIRPORT</th>
<th>- ROI/NPV CALCULATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASSUMPTIONS</strong></td>
<td><strong>SOURCE/COMMENTS</strong></td>
</tr>
<tr>
<td>Hours of operation per day</td>
<td>12</td>
</tr>
<tr>
<td>Energy cost / kwh</td>
<td>0.20</td>
</tr>
<tr>
<td>CO2 kg / kwh</td>
<td>1.22</td>
</tr>
<tr>
<td>CO2 emissions / tonne $</td>
<td>23</td>
</tr>
<tr>
<td>SafeLED IQ @ 2 amp (wattage) incl losses</td>
<td>9.8</td>
</tr>
<tr>
<td>SafeLED @ 6.6 amp (wattage) incl losses</td>
<td>37.8</td>
</tr>
<tr>
<td>w / halogen light (wattage) incl losses</td>
<td>73.1</td>
</tr>
<tr>
<td>LED life hrs (forecast)</td>
<td>100,000</td>
</tr>
<tr>
<td>Halogen life hrs (rated 1500 hrs @ 6.6a)</td>
<td>6,000</td>
</tr>
<tr>
<td>LED life in yrs per hrs of operation</td>
<td>22.8</td>
</tr>
<tr>
<td>Halogen lamp cost</td>
<td>22.20</td>
</tr>
<tr>
<td>Halogen fitting cost</td>
<td>314.00</td>
</tr>
<tr>
<td>LED replacement module cost</td>
<td>29.90</td>
</tr>
<tr>
<td>Inset light , 6.6A cost</td>
<td>546.00</td>
</tr>
<tr>
<td>Inset light, intelligent 6.6 or 2A cost</td>
<td>698.00</td>
</tr>
<tr>
<td>$ Electrician / hr cost</td>
<td>75.00</td>
</tr>
<tr>
<td>Electrician maintenance time / hr / lamp change including travel + misc time</td>
<td>1.50</td>
</tr>
<tr>
<td>Total qty of lights for this exercise</td>
<td>1000</td>
</tr>
<tr>
<td>Analysis period in years</td>
<td>10</td>
</tr>
<tr>
<td>Currency</td>
<td>AUD$</td>
</tr>
<tr>
<td>Discount rate</td>
<td>5%</td>
</tr>
</tbody>
</table>

INSTRUCTIONS:
- Airport to input data in yellow fields to suit local circumstances. (or use default figures on right-hand side).
- Calculations for savings in power, CO2, maintenance, R.O.I., N.P.V., will then be automatically calculated on the following pages.
### INITIAL CAPITAL COST

<table>
<thead>
<tr>
<th></th>
<th>Sell $</th>
<th>Qty lights</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen fitting</td>
<td>314.00</td>
<td>1000</td>
<td>$314,000</td>
</tr>
<tr>
<td>Inset light, 6.6A</td>
<td>546.00</td>
<td>1000</td>
<td>$546,000</td>
</tr>
<tr>
<td>Intelligent light 6.6 or 2A</td>
<td>698.00</td>
<td>1000</td>
<td>$698,000</td>
</tr>
<tr>
<td>LED cost v halogen</td>
<td></td>
<td></td>
<td>$232,000</td>
</tr>
<tr>
<td>LED IQ @ 2A cost v halogen</td>
<td></td>
<td></td>
<td>$384,000</td>
</tr>
</tbody>
</table>

### DATA CALCULATIONS

#### POWER CONSUMPTION COSTS

<table>
<thead>
<tr>
<th></th>
<th>Hrs per day</th>
<th>Days p.a.</th>
<th>Qty lights</th>
<th>kw</th>
<th>kwh p.a.</th>
<th>kwh cost</th>
<th>Cost / 10 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen</td>
<td>12</td>
<td>365</td>
<td>1000</td>
<td>73.1</td>
<td>320,178</td>
<td>$64,036</td>
<td>$640,356</td>
</tr>
<tr>
<td>LED inset light, 6.6A</td>
<td>12</td>
<td>365</td>
<td>1000</td>
<td>37.8</td>
<td>165,564</td>
<td>$33,113</td>
<td>$331,128</td>
</tr>
<tr>
<td>LED IQ inset light, intelligent 6.6 or 2A</td>
<td>12</td>
<td>365</td>
<td>1000</td>
<td>9.8</td>
<td>42,924</td>
<td>$8,585</td>
<td>$85,848</td>
</tr>
<tr>
<td>LED saving vs halogen</td>
<td>35.3</td>
<td>154,614</td>
<td>320,178</td>
<td>$64,036</td>
<td>$640,356</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED IQ @ 2A saving vs halogen</td>
<td>63.3</td>
<td>277,254</td>
<td>$55,451</td>
<td>$554,508</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### CARBON EMISSION & COSTS

<table>
<thead>
<tr>
<th></th>
<th>CO2 kg/kwh</th>
<th>kwh p.a.</th>
<th>total tn CO2</th>
<th>@ $/tn</th>
<th>Cost / 10 yrs / tn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen</td>
<td>1.22</td>
<td>320,178</td>
<td>391</td>
<td>$8,984</td>
<td>$89,842</td>
</tr>
<tr>
<td>LED inset light, 6.6A</td>
<td>1.22</td>
<td>165,564</td>
<td>202</td>
<td>$4,646</td>
<td>$46,457</td>
</tr>
<tr>
<td>LED IQ inset light, intelligent 6.6 or 2A</td>
<td>1.22</td>
<td>42,924</td>
<td>52</td>
<td>$1,204</td>
<td>$12,044</td>
</tr>
<tr>
<td>LED saving vs halogen</td>
<td>1.22</td>
<td>154,614</td>
<td>391</td>
<td>$8,984</td>
<td>$89,842</td>
</tr>
<tr>
<td>LED IQ @ 2A saving vs halogen</td>
<td>1.22</td>
<td>277,254</td>
<td>338</td>
<td>$7,780</td>
<td>$77,797</td>
</tr>
</tbody>
</table>

### MAINTENANCE COSTS

#### LAMP & LED MATERIAL COSTS - MAINTENANCE ANALYSIS PERIOD

<table>
<thead>
<tr>
<th></th>
<th>Lamp life hrs</th>
<th>hrs pd</th>
<th>days pa / lamp</th>
<th>lamps / life</th>
<th>Cost / lamp</th>
<th>Cost/10 yrs/lamp</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen life (est hrs @ lower current)</td>
<td>6,000</td>
<td>12</td>
<td>730</td>
<td>5</td>
<td>$22.20</td>
<td>$111.00</td>
<td>$111,000</td>
</tr>
<tr>
<td>LED module cost</td>
<td>100,000</td>
<td>12</td>
<td>8333</td>
<td>0</td>
<td>$29.90</td>
<td>$-</td>
<td>$-</td>
</tr>
<tr>
<td>LED inset light, 6.6A</td>
<td>100,000</td>
<td>12</td>
<td>8333</td>
<td>0</td>
<td>$29.90</td>
<td>$-</td>
<td>$-</td>
</tr>
<tr>
<td>LED IQ inset intelligent light 6.6 or 2A</td>
<td>100,000</td>
<td>12</td>
<td>8333</td>
<td>0</td>
<td>$29.90</td>
<td>$-</td>
<td>$-</td>
</tr>
<tr>
<td>LED saving vs halogen</td>
<td>94,000</td>
<td>7603</td>
<td>5</td>
<td>-7.70</td>
<td>$111.00</td>
<td>$111,000</td>
<td></td>
</tr>
<tr>
<td>LED IQ @ 2A saving vs halogen</td>
<td>94,000</td>
<td>7603</td>
<td>5</td>
<td>-7.70</td>
<td>$111.00</td>
<td>$111,000</td>
<td></td>
</tr>
</tbody>
</table>

### LABOUR COSTS - MAINTENANCE ANALYSIS PERIOD

<table>
<thead>
<tr>
<th></th>
<th>Maintenance (callout time incl waiting, replacement, etc)</th>
<th>Changeover $/10 yrs</th>
<th>Cost x Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen lamp (no. of lamps x time x hourly rate)</td>
<td>$562.50</td>
<td>$562,500.00</td>
<td></td>
</tr>
<tr>
<td>LED replacement module</td>
<td>$-</td>
<td>$-</td>
<td></td>
</tr>
<tr>
<td>LED saving vs halogen</td>
<td>$562,500.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED IQ 2A saving vs halogen</td>
<td>$562,500.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total material &amp; labour maintenance savings LED</td>
<td>$673,500.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total material &amp; labour maintenance savings LED IQ @ 2A</td>
<td>$673,500.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### SAVINGS CALCULATIONS

<table>
<thead>
<tr>
<th>Lights</th>
<th>W per light</th>
<th>kwh p.a.</th>
<th>% kw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen</td>
<td>1000</td>
<td>73.1</td>
<td>320,178</td>
</tr>
<tr>
<td>Inset light, 6.6A cost</td>
<td>1000</td>
<td>37.8</td>
<td>165,564</td>
</tr>
<tr>
<td>Inset light, intelligent 6.6 or 2A cost</td>
<td>1000</td>
<td>9.8</td>
<td>42,924</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lights</th>
<th>CO2 kg/kwh</th>
<th>kwh p.a.</th>
<th>total tn CO2</th>
<th>% tn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen</td>
<td>1.22</td>
<td>320,178</td>
<td>390.6</td>
<td>100.0%</td>
</tr>
<tr>
<td>Inset light, 6.6A cost</td>
<td>1.22</td>
<td>165,564</td>
<td>202.0</td>
<td>51.7%</td>
</tr>
<tr>
<td>Inset light, intelligent 6.6 or 2A cost</td>
<td>1.22</td>
<td>42,924</td>
<td>52.4</td>
<td>13.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lights</th>
<th>Total Man Hrs</th>
<th>Total $</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen</td>
<td>1000</td>
<td>7,500</td>
<td>$1,313,856</td>
</tr>
<tr>
<td>Inset light, 6.6A cost</td>
<td>1000</td>
<td>-</td>
<td>$331,128</td>
</tr>
<tr>
<td>Inset light, intelligent 6.6 or 2A cost</td>
<td>1000</td>
<td>-</td>
<td>$85,848</td>
</tr>
</tbody>
</table>

### PAYBACK PERIOD CALCULATION - N.P.V.

<table>
<thead>
<tr>
<th>Time in years</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash flow - LED inset light 6.6A</td>
<td>(232,000)</td>
<td>102,611</td>
<td>102,611</td>
<td>102,611</td>
<td>102,611</td>
<td>102,611</td>
<td>102,611</td>
<td>102,611</td>
<td>102,611</td>
<td>102,611</td>
<td>102,611</td>
</tr>
<tr>
<td>Cash flow - LED IQ inset light intelligent 6.6 or 2A</td>
<td>(384,000)</td>
<td>130,581</td>
<td>130,581</td>
<td>130,581</td>
<td>130,581</td>
<td>130,581</td>
<td>130,581</td>
<td>130,581</td>
<td>130,581</td>
<td>130,581</td>
<td>130,581</td>
</tr>
</tbody>
</table>

### NET PRESENT VALUE CALCULATION

| Net Present Value - LED | 560,337 |
| Net Present Value - LED IQ @ 2A | 624,308 |

### INTERNAL RATE OF RETURN

| Internal Rate of Return - LED | 43.0% |
| Internal Rate of Return - LED IQ @ 2A | 31.9% |

### TOTAL COST OVER LIFE BASED ON (10 YEARS)

<table>
<thead>
<tr>
<th>SAVING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen</td>
</tr>
<tr>
<td>LED inset light 6.6A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAVING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen</td>
</tr>
<tr>
<td>LED IQ inset light, intelligent 6.6 or 2A</td>
</tr>
</tbody>
</table>
4.1 Background

AFL facilities at aerodromes provide visual guidance to pilots of aircraft undertaking approach and departure procedures in low visibility and dark conditions. These facilities include, amongst other things, runway lighting, taxiway lighting and visual approach guidance facilities.

The electrical cabling systems for these AFL facilities are unique in having operating arrangements and installation requirements that are significantly different to that normally applicable to domestic, commercial and industrial applications to which the AS/NZS 3000 Standard is particularly directed.

The requirements of AFL are unique because:

» AFL facilities usually include a large number of lights installed over long distances around the airfield.

» The light output from the various lighting facilities required to provide the same light output intensity.

» The light fixtures are generally required to mounted either inset into the pavement or as elevated lights with the light fixtures being no higher than 360 mm above the surrounding ground level.

» Specific power supply and control arrangements are normally provided at aerodromes to ensure these requirements are met.

» The AFL facilities are located within specific security control areas where access is limited and works are restricted and closely monitored.

» The provision of the AFL facilities at aerodromes is covered by Australian and international regulations and standards. The various recommendations and requirements set down in those documents require unique installation methodologies for the provision of power supply to those AFL facilities.

Series current cabling systems

To achieve the required light intensity outputs from the facilities, the international practice is to use series current power supply systems in place of the normal parallel voltage systems (refer to International Civil Aviation Organisation Aerodrome Design Manual Parts 4 and 5 for further reference on these requirements).

The series current systems utilise ‘constant current’ power supplies with a single ‘primary’ cable in the form of a loop carrying the current (amperage) to each light.

The primary cables are normally isolated from earth and the mains supply.

The lights forming the AFL facilities are connected in series with the primary cable via series isolating current transformers (SITs). SITs usually have a 1:1 ratio with one SIT for each light so that when a light fixture lamp filament fails the primary circuit does not go open circuit ensuring that the remaining light fixtures continue to operate.

The series current systems provide the same light intensity from each lamp connected to the system because the same current (amperage) value passes through each lamp filament in the facility.

The current (amperage) used for AFL systems is normally a maximum of 6.6 A although other current values are sometimes used (some systems use 20 A). The series current value may be changed to lower currents (amperages) by the power source to vary the intensity of the lights (lower current through the lamp filaments) to allow the light output from the various AFL facilities to match the current ambient light conditions.

The series current systems have a number of significant operational advantages over the normal parallel voltage systems. Depending on the size of the aerodrome and the type of light fixtures, the cabling systems for these facilities may require system supply voltages in excess of 1,000 V, in which case the systems are deemed as high voltage (HV) systems.

The power supply for the AFL series current systems is provided by constant current regulators (CCRs) or mains isolating transformers (MITs).
The CCRs and MITs both provide very low fault level systems.

CCRs and MITs may be required to provide HV outputs to achieve the required series current values.

4.2 History

Historically, the cabling systems for the AFL facilities supplied by series current systems, or ‘constant current’ power supply systems, have utilised installation methodologies different to that required by AS 3000 (Wiring Rules) and AS 2067 (Substations and high voltage installations exceeding 1 kV AC).

As the series current systems and the cable used for these systems was significantly different from normal electrical practice, and the systems were installed within the airside restricted area of aerodromes where strict control on access and all types of works are maintained, the Department of Civil Aviation (DCA) referred the matter to the Standards Association of Australia in 1958.

Committee EL/1, the committee responsible for the SAA wiring rules, advised DCA in 1959 that it recommended to all statutory authorities that such series current installations be treated as ‘unusual installations’ that did not have to strictly comply with certain parts of the wiring rules, provided appropriate precautions were observed.

The exemption allowed unarmoured cable to be used for high voltage and that the cable could be installed at a depth providing 450 mm cover over the cables in place of the standard 750 mm required for high voltage cables.

It also allowed the cable to be buried directly in the ground without mechanical protection.

The exemption was allowed only for the area of the installation within the ‘airside’ restricted portions of the aerodrome movement areas and did not apply to public areas.

The exemption was reaffirmed to the Department of Aviation in 1983, and again to the Civil Aviation Authority in 1993.

This exemption allowing the use of the alternative installation methodology has been recognised by the Civil Aviation Safety Authority (CASA) and have been promulgated in the CASA Manual of Standards Part 139 Chapter 9.22.

The exemption has since been allowed to lapse and current installation practices have changed. However, for operational and maintenance reasons it is desired to continue with the installation of the cabling systems at depths less than 750 mm.

4.3 Previous installation methodology

Generally, the series current cabling systems utilised special non-armoured cables either 3,000 V rated or 5,000 V with PE, XLPE or EPR insulation, PE or Nylon sheath, and a 6² mm seven-stranded copper conductor.

Where installed within the controlled and restricted area of aerodromes the cables were normally installed direct buried with 450 mm cover or in heavy duty conduits with 450 mm cover.

4.4 Current recommended installation methodology

Installation of the AFL cabling using the direct buried methodology has been found to provide a reduced capital cost but has major limitations for the ongoing serviceability of the facilities in that the cable is more prone to damage and fault finding is very painstaking, difficult and costly.

The desired arrangement is now for installation of the cables and SITs in pit and duct systems. This allows easy installation of the cables, provides additional mechanical protection for the cables and SIT, and provides a major improvement in the maintainability of the equipment.

One major issue for pit and duct systems being used for HV equipment is that, to comply with AS/NZS 3000 Part 2 and AS 2067, the cables must be provided 750mm cover. Providing 750mm cover requires large pits to allow reasonable access for maintenance of the cables and equipment. The provision of large pits, particularly in the runway graded strip, creates issues such as support for aircraft wheel loadings, as well as being of very high cost.
Currently it is seen that the installation of AFL cabling in Class A type installation suitable for compliance with AS/NZS 3000 is the most desirable arrangement for AFL systems. This arrangement allows the use of off the shelf-type pits which generally meet the required for installation of equipment in runway strips but requires special consideration to comply with the electrical installation requirements.

4.5 Compliance with AS/NZS 3000 Requirements

**Australian Standards requirements**

Clause 7.6 of AS/NZS 3000:2007 requires that electrical installations operating at high voltage shall be installed in accordance with the requirements of AS 2067:2008.

AS 2067:2008 Clause 4.2.9.1 cables requires that HV installed underground be buried at a depth of not less than 750 mm with mechanical protection as specified in AS/NZS 3000:2007.

AS/NZS 3000:2007 Table 3.5 Underground Wiring System Categories details the particular mechanical requirements for the various cable types and details the installation requirements for Category A wiring systems, Category B wiring systems and Category C wiring systems.

Table 3.5; options for underground wiring systems include (amongst other things):

a) sheathed, armoured and served cables buried direct in ground,

b) insulated unsheathed cables installed in heavy duty conduit, and

c) insulated and sheathed cables installed in heavy duty conduit.

AS/NZS 3000:2007 Table 3.6 Underground Wiring System - Minimum Depth of Cover specified that Category A and Category B wiring systems must have a minimum of 500 mm cover.

AS/NZS 3000:2007 Clause 3.11.4.5 Identification of underground wiring requires the provision of orange marker tape to identify underground wiring systems.

**Compliance by Specific Design and Installation**

Part 1.9.4.1 of AS/NZS 3000:2007 wiring rules states:

“Certain electrical installations or portions of electrical installations, because of their unusual requirements, application or intended use, that cannot meet Part 2 of this Standard, may use a specific design and installation method as detailed below.”

Such installations may be deemed suitable provided that, having due regard to all the circumstances associated with the intended application, they—

a) satisfy the fundamental safety principles of Part 1 of this Standard (AS/NZS 3000:2007); and

b) will result in a degree of safety from physical injury, fire and electric shock not less than that which, in other circumstances, would be achieved by compliance with the particular requirements of this Standard; and

c) satisfy the other requirements of this Standard as detailed in this Clause.

The remaining portions of such installations shall comply with Part 2 of this Standard.”

**Acknowledgement and documentation requirements for the application of AS/NZS 3000:2007 Part 1 Compliance by Specific Design and Installation**

Part 1.9.4.2 of AS/NZS 3000:2007 wiring rules states:

Any departures from Part 2 of this Standard must be formally acknowledged by the owner or operator of the installation.

Part 1.9.4.3 of AS/NZS 3000:2007 wiring rules states:

The designer shall document the Part 1 design. Such documentation shall be in the English language and detail:

i) why Part 2 of this Standard was not adopted; and

ii) the verification requirements that are required to be undertaken to ensure full compliance with this Standard; and

iii) how compliance with Part 1 of this Standard is being achieved; and
iv the owner or operator’s acknowledgment as to any departure from Part 2 of this Standard; and

v any requirements where the design requires specific installation use by the owner or operator of the electrical installation and provide a copy of these requirements to the owner or operator; and

vi the verification undertaken to ensure full compliance with this Standard, and the results of this verification.

Such documentation shall be retained by the designer and also on-site at the electrical installation, by the person with overall responsibility for the installation.

Part 1.9.4.4 of AS/NZS 3000:2007 wiring rules states:

All parts of an electrical installation that do not comply with Part 2 of this Standard shall be verified as complying with the specific design and with Part 1 of AS/NZS 3000:2007 prior to being placed in service.

Part 1.9.4.5 of AS/NZS 3000:2007 wiring rules states:

Persons undertaking designs that depart from Part 2 of this Standard shall be competent.

Specific design and installation methodology for AFL series current systems with aerodrome controlled and restricted areas

To take advantage of the AS/NZS 3000 Part 1 allowance it is proposed to utilise cables rated at 5,000 V, with a stranded 6\(^2\)mm copper conductor, EPR, PE or XLPE insulation, and with a PE or HDPE sheath.

The cables shall be installed in heavy duty rigid orange coloured conduit, compliant with the requirements of AS/NZS 3000:2007, installed with a minimum depth of cover of 500 mm.

The conduit shall be installed with an orange PVC warning tape above the conduit as required by AS/NZS 3000:2007.

Variation from the requirements of AS/NZS 3000:2007 Part 2

The method of installation meets all of the material and installation requirements of AS/NZS 3000:2007 for LV systems.

Where the system output voltage is HV (=>1,000 V), the method of installation meets the requirements of AS/NZS 3000:2007 with the exception of the installation depth of the cables required by AS/NZS 3000:2007 Clause 7.6 and the subsequent requirement’s of AS 2067:2008 Clause 4.2.9.1, where the cable is required to be provided with minimum depth of cover of 750 mm.

Reason for the recommendation of AS/NZS 3000:2007 Part 1 Compliance by Specific Design and Installation

The AFL installations utilise series current systems that are unique in having operating arrangements and installation requirements not specifically addressed in AS/NZS 3000:2007.

The lighting facilities have light fixtures installed over long distances around the aerodrome and incorporate a large number of lights separately located along the runways and taxiways within the aircraft movement area.

The light output from the numerous light fixtures within the particular facility is required to emit the same intensity of light.

Current transformers (SITs) are required for each light adjacent to or near the light locations with the transformers being required to be installed in field mounted pits.

The requirements of AS/NZS 3000:2007 for depth of cover for HV AFL series current systems are not met due to the large number of size limited aircraft load rated pits required to be installed within the aerodrome movement area, the associated difficulty of installation and maintenance of the cabling and SITs, and the nature of operations at the airport requiring the urgent repair of facilities in the event of equipment failure.

In addition, the nature of the airport operations involves limited access to the aerodrome movement area with immediate clearance of areas frequently required.
Justification

The AFL installations utilise series current systems that are unique in having operating arrangements and installation requirements not specifically addressed in AS/NZS 3000:2007.

i Compliance with Part 2 of AS/NZS 3000:2007 is not being met only for the lighting and cabling systems installed within the specific restricted aircraft movement area where access is strictly controlled with authorised personnel only allowed access;

ii Works within the aerodrome movement area are strictly controlled and due to the nature of operations at the airport works are normally limited to good weather usually during the day;

iii Works are continuously observed by Airport Safety Officers who are familiar with the operation of the aerodrome and the location of the facilities at the aerodrome;

iv Cable routes of the AFL cabling are normally identified by cable markers or clearly identifiable due to the location of the transformer pits for the lights.

v Location of the field cables and light fixture equipment are recorded on ‘as constructed’ drawings which are held by the aerodrome operator for future reference;

vi Field cabling and equipment location records are required to be kept up to date from the initial installation and as changes occur;

vii Maintenance is undertaken by personnel familiar with the theory, operation and maintenance of AFL series current systems and familiar with the AFL facilities at the particular aerodrome;

viii AFL systems are designed to be isolated from the ‘mains’ supply and from earth; and

ix AFL systems generally have very low fault level (typically less than 10A).

Fundamental safety principles

Principle safety requirements details in AS/NZS 3000:2007 Part 1.5 include:

» Protection against dangers and damage;
» Control and Isolation;
» Protection against electric shock;
» Protection against thermal effects in normal service;
» Protection against overcorrect;
» Protection against earth fault currents;
» Projection against abnormal voltages;
» Protection against the spread of fire;
» Protection against injury from mechanical movement; and
» Protection against external influences.

The installation methodology of HV AFL cables within the aerodrome controlled movement area detailed herein varies from the requirements of AS/NZS 3000:2007 only by the requirement for depth of cover.

The installation methodology detailed herein does not increase the safety risk detailed in AS/NZS 3000:2007 and does not change the principle safety requirements due to the particular system arrangements and operational procedures required to be in place in the strictly controlled aerodrome movement area as detailed herein.
CS5. SERVICEABILITY CHECKLIST

An aerodrome reporting officer (ARO) serviceability inspection must be conducted each day that an airline service operates at an aerodrome or in any case at least twice a week.

Airports with dedicated maintenance staff would use a list similar to that below. AROs may use this for their serviceability inspections and pass information on as required.

5.1 Basic airport

AIRFIELD LIGHTING INSPECTION CHECKLIST

<table>
<thead>
<tr>
<th>DATE:</th>
<th>/</th>
<th>/</th>
<th>DURATION</th>
<th>WEEKLY</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>TYPE COLOUR</th>
<th>STATUS</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUNWAY LIGHTS WHITE</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>THRESHOLD LIGHTS GREEN</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>RUNWAY END LIGHTS RED</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>TAXIWAY EDGE LIGHTS BLUE</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>TAXIWAY HOLDING POINT LIGHT YELLOW</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>IWI LIGHTS WHITE</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>APRON FLOODLIGHTS WHITE</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
</tbody>
</table>

ACTION

FAULTS REPAIRED BY: / / MAINTENANCE COMPLETED BY: / / HOURS:

UNABLE TO EFFECT REPAIRS AND FOLLOWING ACTION TAKEN

-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------

INSPECTION BY: / / TIME:
5.2 Intermediate airport

**AIRFIELD LIGHTING INSPECTION CHECKLIST**

DATE: / / DURATION / WEEKLY

<table>
<thead>
<tr>
<th>TYPE</th>
<th>COLOUR</th>
<th>STATUS</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUNWAY EDGE LIGHTS</td>
<td>WHITE</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>THRESHOLD LIGHTS</td>
<td>GREEN</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>RUNWAY END LIGHTS</td>
<td>RED</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>TAXIWAY EDGE LIGHTS</td>
<td>BLUE</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>TAXIWAY CENTRELINE LIGHTS</td>
<td>GREEN</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>TAXIWAY HOLDING POINT LIGHTS</td>
<td>YELLOW</td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>PAPI</td>
<td></td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>IWI LIGHTS</td>
<td></td>
<td>OK / FAULTY</td>
<td></td>
</tr>
<tr>
<td>APRON FLOODLIGHTS</td>
<td></td>
<td>OK / FAULTY</td>
<td></td>
</tr>
</tbody>
</table>

**ACTION**

FAULTS REPAIRED BY: / / MAINTENANCE COMPLETED BY: / / HOURS:

UNABLE TO EFFECT REPAIRS AND FOLLOWING ACTION TAKEN

INSPECTION BY: / / TIME:
CS6. COMMISSIONING CHECKLIST

MOS-139 Chapter 9.1.15 Commissioning of Lighting Systems refers. Typical checklists follow.

6.1 Airfield lighting commissioning checklist

EXAMPLE OF TYPICAL CHECKLIST

Location: ........................................................................................................................................

Project: .......................................................................................................................................... 

Reference: ......................................................................................................................................

Circuit: .......................................................................................................................... Validation Date: / /
<table>
<thead>
<tr>
<th>Dwg No.</th>
<th>Pit No.</th>
<th>Label</th>
<th>Fitting Type</th>
<th>Colour</th>
<th>SIT Size</th>
<th>Circuits Labelled as Per Spec</th>
<th>Fitting Type Installed As Per Drawings</th>
<th>Light Colour is Correct</th>
<th>Orientation of Light Fitting is Correct</th>
<th>Light on correct Circuit</th>
<th>Mechanical Installation / Bolts Torqued</th>
<th>Correct currents set</th>
<th>Checked By</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dwg No.</td>
<td>Pit No.</td>
<td>Label</td>
<td>Fitting Type</td>
<td>Colour</td>
<td>SIT Size</td>
<td>Circuits Labelled as Per Spec</td>
<td>Fitting Type Installed As Per Drawings</td>
<td>Light Colour is Correct</td>
<td>Orientation of Light Fitting is Correct</td>
<td>Light on correct Circuit</td>
<td>Mechanical Installation / Bolts Torqued</td>
<td>Correct currents set</td>
<td>Checked By</td>
<td>Notes</td>
</tr>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.2 Precision approach path indicator (PAPI) commissioning checklist

EXAMPLE OF TYPICAL CHECKLIST

Location: .....................................................................................................................................................

Project: ....................................................................................................................................................

Reference: ..................................................................................................................................................

Circuit: ..................................................................................................................................................... Validation Date:   /   /
<table>
<thead>
<tr>
<th>PAPI No.</th>
<th>Required Lamp Wattage</th>
<th>Check Lamp Wattage</th>
<th>Check Foundation Dimension Including Cable Entry</th>
<th>Check Level &amp; Tightness of Bolts</th>
<th>Check all Electronic Connections</th>
<th>Check Operation of Lighting</th>
<th>Check Covers Secured</th>
<th>Flight Test</th>
<th>Checked By</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAPI Box A</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Deg/Min</td>
<td>Y/N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAPI Box B</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Deg/Min</td>
<td>Y/N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAPI Box C</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Deg/Min</td>
<td>Y/N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAPI Box D</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Deg/Min</td>
<td>Y/N</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Current Settings for XX PAPI System (*These may change according to findings of flight test)

<table>
<thead>
<tr>
<th>Intensity TYPE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (Amps) Design/Commissioned</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:

During the ground survey and flight test:

☐ Check each intensity level is set to the design currents prior to flight test.

☐ Check PAPI system intensity matches runway lighting intensity for each stage setting during flight test. Adjust as advised by flight test pilot and record commissioning currents.

☐ Check for “on slope” for harmonisation with ILS glide slope, if present. Check horizontal beam splay meets 15 degrees.

☐ Check the elevation angles of each box are set to design angles prior to flight test. Adjust as advised by flight test pilot and record final setting angles. Place labels in each box recording these commissioning setting angles. As part of the ground survey, check for obstacles in the OLS.

SIGN OFF: Installation Representative

Printed Name:..............................................................................................................................................

Signature:.................................................................................................................Date / /

SIGN OFF: Airport Representative

Printed Name:..............................................................................................................................................

Signature:.................................................................................................................Date / /
6.3 Apron Floodlighting Commissioning Methodology

Acknowledgement and thanks to Perth Airport.

6.3.1 Purpose

This document details the strategy for the maintenance of all Perth Airport Apron floodlights from the perspective of:
» Maintenance Methods
» Levels of Service

6.3.2 Scope

This procedure applies to the maintenance of all Perth Airport Apron Flood Lights.

6.3.3 Definitions

For the purposes of this procedure, the following definitions apply:

PM
Preventative Maintenance – Time based maintenance which encompasses the practice of periodically doing a task that will improve equipment reliability. PM can be described as lubrication, changing of a filter, cleaning, or intrusive maintenance such as an major overhaul.

PdM
Predictive Maintenance – Condition based maintenance that encompasses periodically applying condition based monitoring technology such as vibration, oil analysis and adopting processes to detect the onset of failure.

PaM
Proactive Maintenance – Root caused maintenance, but is not strictly maintenance oriented. It requires the review of design, procurement, spares management, start-up operation and maintenance for eliminating the defects that are at the root cause of maintenance requirements.

RM
Reactive Maintenance – Maintenance that is performed only when it is identified that it is required, i.e. the machine has stopped.

AU/OAU
Asset Utilisation/Overall Asset Utilisation. Percentage of absolute perfect operation of a given process. For example running a plant 8760 hours per year at 100% of maximum, demonstrated, sustainable rate.
6.3.4 Governing standards

Australian airfield apron flood lighting installations are governed by regulatory and safety requirements according to CASA (Civil Aviation Safety Authority) as detailed in the MOS (Manual of Standards) 139 Chapter 9. It is determined to base the minimum design for Perth Airport Apron Floodlighting on Code 3C Aircraft. The following are relevant excerpts from the standard:

- Apron floodlighting shall be provided on an apron and on a designated isolated aircraft parking position
- Apron floodlights shall be located so as to provide adequate illumination on all apron service areas, with a minimum of glare to pilots of aircraft in flight and on the ground, aerodrome and apron controllers, and personnel on the apron
- The arrangement and aiming of floodlights shall be such that an aircraft stand receives light from two or more directions to minimise shadows.
- The spectral distribution of apron floodlights shall be such that the colours used for aircraft marking connected with routine servicing, and for surface and obstacle marking, can be correctly identified.
- Horizontal luminance 20 lux with a uniformity ratio (average to minimum) of not more than 4 to 1; and Vertical luminance 20 lux at a height of 2 m above the apron in relevant directions. Other apron areas:
  - Horizontal luminance 50 per cent of the average luminance on the aircraft stands with a uniformity ratio (average to minimum) of not more than 4 to 1.
  - Each minimum luminance value mentioned in this Section is maintained luminance below which the actual value must not fall
  - Each floodlight design must meet a target value which allows for a depreciation and maintenance factor that is appropriate for the particular floodlight system

AS/NZS 3827.1 – Lighting System performance
AS/NZS 3000

6.3.5 Calculation of grid size

Governing Standards do not provide a recommended grid size. There are a number of other industry norms that do provide guidance such as

1. Maximum grid size using AS 2560.1 2m
2. Maximum grid size using EN 12464-2 3.6m
3. Maximum grid size using AS 1680.5 5m

It can be seen in the table below that actual average horizontal and vertical lux based on various grid sizes does not yield a considerable amount of difference in actual readings, in fact the greater the grid size the more conservative the readings.

<table>
<thead>
<tr>
<th>Calculation Grid Size (m)</th>
<th>Average Horizontal Lux</th>
<th>Average Vertical Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 2</td>
<td>40.93</td>
<td>22.47</td>
</tr>
<tr>
<td>3.6 x 3.6</td>
<td>41.12</td>
<td>22.32</td>
</tr>
<tr>
<td>5 x 5</td>
<td>40.67</td>
<td>22.00</td>
</tr>
<tr>
<td>10 x 10</td>
<td>39.47</td>
<td>21.43</td>
</tr>
</tbody>
</table>

In the Australian airfield industry a 10m grid is commonly used and PAPL has adopted this same work practice.

Lux testing methodology

The following is the methodology that Perth Airport has determined from MOS 139 section 9.16.1 for test Lux readings.

- Horizontal Light readings shall be measured at ground level at each grid point.
- Vertical light readings shall be taken 2 m above ground level and in the direction of the light source parallel to the parking centreline. (typically in the same direction the Aircraft is facing)

Any other methodology used in the design of Apron flood lighting on Aircraft parking bays will be confirmed using the design methodology at commissioning, and then verified using the PAPL methodology as per MOS 139.
### APRON FLOODLIGHTING LIGHT READING TEST SHEET

<table>
<thead>
<tr>
<th>Distance From Stop</th>
<th>Vertical Average Intensity</th>
<th>Horizontal Average Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>50m</td>
<td>4.9</td>
<td>23.6484</td>
</tr>
<tr>
<td>40m</td>
<td>7.5</td>
<td>28.93145</td>
</tr>
<tr>
<td>30m</td>
<td>7.1</td>
<td>7.24786</td>
</tr>
<tr>
<td>20m</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>10m</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>30m</td>
<td>4.9</td>
<td>23.6484</td>
</tr>
<tr>
<td>40m</td>
<td>7.5</td>
<td>28.93145</td>
</tr>
<tr>
<td>30m</td>
<td>7.1</td>
<td>7.24786</td>
</tr>
<tr>
<td>20m</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>10m</td>
<td>5.1</td>
<td>5.1</td>
</tr>
</tbody>
</table>

**4:1 Ratio**
- Horizontal: 23.6484
- Vertical: 7.24786

**Climatic Conditions:** CLEAR

**Number of Lights Operating:** 100

**Start Position co-ordinate:** 63734.18 265576.99

**CAD FILE:** APRON FLOODLIGHTING GRIDS

**Legend:**
- **PASS**
- **40m**
- **30m**
- **20m**
- **10m**
- **Stop Bar**

**Note:**
- Distance Reading: Taken at the highest sensor facing direction of Centre Line. Horizontal Reading: Taken at ground height with sensor facing up.
6.3.6 Apron flood lighting maintenance plan

The following details maintenance strategies for Apron Flood Lights. It is well documented that that where PM, PdM, MMS and Planning are used as tools to understand root cause, to prioritise resources, to eliminate defects and to be proactive, result in most improved uptime or AU. This ‘reliability’ based maintenance approach is applied for the maintenance of Apron Floods.

Preventative maintenance plan

» Complete structural assessment of poles older than 25 years
» Airside Apron Flood Light 1 Monthly Inspection
» Periodic LUX testing on Specified Bays

Reactive maintenance plan

Apron floodlight outages are reported by:
» Night time inspections conducted by Operations Safety Officers
» Monthly inspections by the Electrical Department.

These outages are logged on a monthly inspection sheet.

Once a month the inspection sheet detailing the number and position of the apron flood lights will be reviewed and a decision made upon what lamps will be replaced for the month. The actual decisions made will be based on:
» Vicinity of the lamps to other lamps due for PM
» Access to the lamps that need replacement
» Available resources
» Serviceability

Predictive maintenance plan

Program of delivered PdM is as determined below:

Different methods have been trialled to most effectively maintain and test to ensure compliance on the Aircraft Parking Bays.

Bulk lamp changes were conducted over a period of time when individual lamps failed on Apron flood lighting towers. This practice was deemed unsuccessful in terms of reliability and cost effectiveness due to new lamp failures, and that it did not provide any noticeable increase to Lux levels above what was already achieved.

Based on the above a decision has been made by the electrical department to maintain apron lighting with differing strategies.

Some Bays will not undergo lux testing.
» The Aircraft Lux Testing Schedule is located on the PAPL Intranet. Below is the determination of the above:
» Lux Level Readings on all high priority passenger loading bays every two years. Generally towers with multiple lights.
» Lux Level readings every 2 years on Low priority parking bays with easy access and where it is more cost effective to test than bulk lamp change
» Bulk replacement every two years on low priority parking bays where night time access is not practical in lieu of Lux testing.
» Any Aircraft parking bay that has been determined as requiring additional engineering by previous Lux testing will not be re-tested until such time that the lighting has been re-designed and commissioned.

Failed lamps will be individually replaced as per the normal maintenance regime.

Future Works

Future work is also required outside of lux reading that includes power quality to the apron flood lights. Not only for the purposes of energy reconciliation, power supplies to flood lights should be monitored in terms of:
» Voltage
» Current
6.3.7 MMS

Apron flood lighting entry

All Apron Flood Lighting will be entered into the MMS system where:

» Asset Number will be issued by the MMS system with a suffix of ‘E’
» Asset Short Description will be the ‘Apron Flood’
» Asset Search Description will be the equipment Number 003
» Asset Description is the location of the Asset – which Apron it is located

6.3.8 Process

Spreadsheets

Until the introduction of MMS, Spreadsheets have been developed by the Electrical Infrastructure Department that are used as the tool to plan and monitor the maintenance of the Apron Floodlighting. Details on every lamp and tower consist of:

» Location
» Installed Year
» Column Height
» Column Type
» Column Manufacturer
» Spigot Diameter
» Catenary
» Number of Fittings
» Light Fitting Type and Manufacturer
» Lamp Type
» Lamps per Fitting
» Twr Total Lamps
» Lamp Cat
» Ballast Type
» Ignitor Type
» Control Gear Location
» Supply Point
» Circuit
» C/B or Fuse Rating at base
» ESS/NON ESS
» Control Type
» Schematic Drawing Number
» Tower Label Fitted
» Switch board legend
» Catenary Installed
» Comments
» Circuit metered Y/N
» XVIII. Electricity Meter Number
» XXIX. Space for Meter Installation Y/N.

Inspection sheets

Inspection sheets have been developed for Apron flood lighting that are task orientated and are the tool used to ensure uniform reporting. The inspection sheets will be managed by the Airfield Lighting group and held on the intranet. Any outstanding works identified by the inspection sheets, will have works orders raised against them using the WASP system. Remedial works will be planned and rescheduled for completion dependant on criticality.

Photometric testing

Photometric testing is completed as part of the Preventative maintenance program. All data is recorded into a spreadsheet that is then stored on InSite.

Stock and stock management

Perth Airport Electrical control and hold a small stock of Apron flood lighting fittings / lamps and towers. This stock allows for the recovery from small unplanned failures and to assist projects where the delivery is business critical minimising risk in relation to long lead time items.

Stock management is a key area that needs further work, in how it relates to:

» In House Stock
» Just in Time Procurement

In both cases it is currently assumed that stock is transported, stored, rotated, installed and put into service (Start-up) in accordance with a strategy that maximise the life of the lamp beyond the early infant mortality failure.
Appendix 1 — Light loss factor

To understand best a maintenance strategy for lighting, the Light Loss Factor or Maintenance Factor must first be understood. Consultation with actual lamp supplier for the lumen depreciation factor should be sort where the following is provided as a guide.

<table>
<thead>
<tr>
<th>Cleaning interval/months</th>
<th>Luminaire Maintenance factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IP2X min (a)</td>
</tr>
<tr>
<td></td>
<td>High pollution (b)</td>
</tr>
<tr>
<td>12</td>
<td>0.53</td>
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<tr>
<td>18</td>
<td>0.48</td>
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<tr>
<td>24</td>
<td>0.45</td>
</tr>
<tr>
<td>36</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Appendix 2 — Proactive maintenance

For completeness proactive maintenance in relation to Apron Floods needs to remain in the forefront of any maintenance strategy. The approach for the implementation of Proactive Maintenance as it applies to apron floods lies in the understanding of new technology LED technology, management of total cost of ownership that encompasses operating costs, maintenance, storage of spare parts, installation and start-up noting failures are likely to occur at start-up.