AVIATION SAFETY DEPARTMENT

Electrical Systems

Guidance Material

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Foreword

This document has been compiled to enhance aviation safety in the aerodrome's environment. It is not intended to supersede or replace existing laws or regulations produced by the DGCA of the State of Kuwait. The distribution or publication of this document does not prejudice the State's ability to enforce existing National rules and regulations as stipulated in the KCASRs.

To the extent of any inconsistency between this document and the National law, regulations (KCASRs), Safety Bulletins and advisory publications shall prevail.

Scope

This document is intended to provide guidance for aerodrome operators and other stakeholders involved in Electrical Systems.

Aviation Safety Director

Engr. Hussam Al-Rasheed
Aviation Safety Director

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Table of Contents

CHAPTER 1

ELECTRICITY SUPPLIES

1.1 GENERAL

The supply of power for aerodromes should be determined before the design of the aerodrome lighting installations is initiated. The electrical power requirement for visual aids lighting facilities is usually only a small part of the total electrical power used by the aerodrome. Whether the visual aids being installed are for a new aerodrome or for modernization and expansion of an existing aerodrome, the sources of power should be analyzed for availability, capacity, reliability, and practicality for the proposed installation and for future expansion. This analysis should include consideration of requirements of Annex 14, Volume I, Table 8-1 for use in cases of failure or malfunction of the normal power supply.

1.2 SOURCES OF POWER TO THE AERODROME

1.2.1 Commercial/Public Power Source

Most aerodromes obtain power through means of feeders from an interconnected electricity network outside the aerodrome. For major airports, it is desirable to have at least two independent incoming power sources coming from widely separated sections of the electricity network beyond the aerodrome, with each supplying separate substations on aerodrome property. Because the outside network is usually interconnected, in reality it may not be possible to identify sections that are truly independent. Selection is, therefore, on the basis of least probability of simultaneous failure of both sources.

Power to the aerodrome main power substation is usually supplied at a high voltage (over 5 000 volts). The voltage is reduced at the aerodrome substation to an intermediate voltage (2 000 to 5 500 volts) for distribution within the aerodrome. A further step-down of voltage may be necessary to match the required input voltage of visual aids equipment.

Within the aerodrome, reliability of the supply of power to the individual stations can be improved by using a closed ring high-voltage input circuit with balanced voltage protection on the distribution transformers or by using a double loop system from independent primary sources operating as open rings fed from two transformers at each station.

With the use of centralized monitoring of fault currents and thereby operation of transfer switches within the loops, the impact of power failures can be minimized. Simpler arrangements providing lesser reliability may be used at smaller airports.

1.2.2 Independent local power source

In addition to a public source, some aerodromes for economic reasons may have their own plant facilities for the supply of power. The local power source may be in the form of a diesel-electric generator unit, gas engine, turbine generator or even solar power plant such as that shown in Figure 3-1. As a result of their nature, aerodromes tend to have large areas of open unused land. The design/orientation of solar power plants should be such as to avoid possible glare to pilots, glare to the control tower and interference with electronic navigational aids at the aerodrome

1.3 POWER SUPPLY TO AERODROME VISUAL AIDS

The design objective for the lighting system is such that, upon occurrence of failure or malfunction of the "normal" supply, automatic transfer takes place to the "standby" supply within a specified period of time.

It is of importance to note that the designations of "normal” supply and "standby” supply are simply labels that are applied to power sources as appropriate for the mode of operation and interruption time. Typically, an aerodrome would have a public power source and a diesel-electric generator unit or interruptible power unit (IPU) for the lighting systems. As shown in Figure 3-2, in the case of non-precision approach and precision approach category I, the IPU would be labelled as "standby" and the public power source as "normal", for reason that the IPU can be started and stabilized within the maximum time period of 15 seconds. In the case of precision approach category II/III and for take-off in RVR less than 800 m, the stipulated transfer time of 1 second requires that the IPU first be brought into operation, thus labelled as "normal" and the public power source labelled as "standby". Other options include the method of powering from a static uninterruptible power unit (SUPU) for lighting that needs a maximum 1-second interruption. Compared to the method in which an IPU is first activated, this method is favorable in terms of fuel cost and environmental benefit. The airport should select the most suitable method taking into consideration power supply condition and cost-performance for the site.

A simple way of looking at this is to consider "supply" as the electricity itself and “source” as the origin of the supply. Which source is the origin of which supply (normal or standby) is dependent upon the mode of operation as shown in Table.

The terms "primary" and "secondary" tend to be considered as permanent labels as to identify specific equipment, whereas the operational use of the terms "normal" and "standby" could be more appropriate since they point to the operational use of the equipment.

Supply versus mode of Operation	**Normal Supply**	**Standby Supply**
Category 1	Public Power Source	Local Generator
Category II/III	Local Generator	Public Power Source

Although the use of a second public or local independent power source is feasible, it is preferable that the aerodrome visual aids be provided with its own local power source in the form of an engine-generator set with capacities ranging from 50 to more than 1 000 kVA. This local power source should be capable of supplying power for a time period that exceeds the maximum time needed to restore power from the primary source. Engine-generator sets are often expected to operate for 24 to 72 hours without refueling.

1.3.1 Synchronization

As an alternative to separate switching of the normal and standby power supplies, the emergency power unit (IPU) may be synchronized with the public source, i.e. coupled together to operate in unison, as shown in Figure 3-3. This offers better efficiency of the generated power and eliminates interruption of power supply to the constant current regulators (CCRs). In this case, labelling for a "normal " or "standby" supply is not used, since in a sense either label would apply.

1.4 UNINTERRUPTIBLE POWER SUPPLY

Another alternate method utilizes an uninterruptible power supply (UPS) (sometimes called uninterruptible power source or uninterruptible power system). As shown in Figure 3-4, for initial operation the public source is the normal supply to the CCRs. With failure of the public source a two-step process then takes place. In Step 1, the UPS provides power to the CCRs. This step may last for 15 to 30 minutes or more depending upon the size of the batteries. Prior to exhaustion of the batteries, the IPU is started so that it is available to take over the load in Step 2.

In as much as the CCRs are not exposed to an interruption for start-up of the standby supply, the process can similarly be applied for category II/III operations. The benefit for the airport is twofold. Since the IPU is the standby supply for category II/III, its hours of operation are substantially reduced leading to economies for fuel consumption and maintenance. Reduction occurs as well for category I operations

since the UPS can provide power for failures of the public source which are less than 30 minutes.
The associated benefit is environmental in that a reduction in hours of operation of the IPU also reduces emissions and thus the carbon footprint of the airport.

A further optimized method to meeting required interruption time is to separate out particular lighting facilities such as that for runway edge and runway centerline/touchdown zone lighting, so that the latter is supplied by the UPS. In this fashion, the IPU serves as standby for all facilities under category II operations according to Annex 14, Volume I, Table 8-1. When transfer occurs, the UPS provides power to the runway centerline/touchdown zone lighting to meet the 1-second requirement whilst the runway edge lighting waits through the 15-second start-up for the IPU.

The UPS often comes in the form of an electronic package with a battery bank for storage of energy and is referred to as a static uninterruptible power unit (SUPU). A UPS consisting of an engine and an electric generator with a flywheel for storage of energy is a rotary uninterruptible power unit (RUPU). The RUPU, used at numerous airports, fell out of vogue due a variety of issues albeit it is being considered more often today due to advancements in the technology.

Secondary Power Supply requirements for Visual Aids:

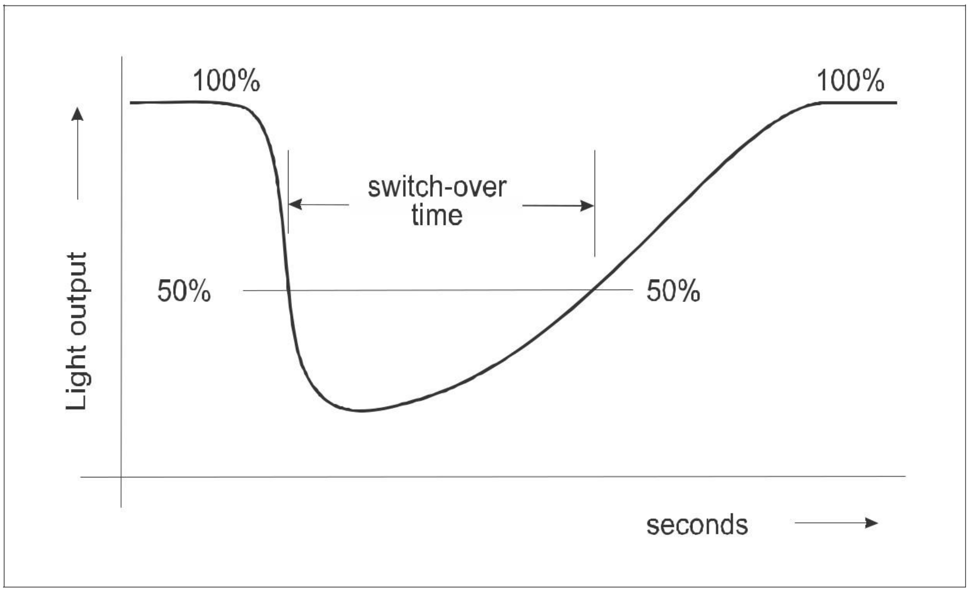
Runway Lighting aids requiring	Runway Lighting aids requiring	Runway Lighting aids requiring
Non-precision approach	Approach lighting system Visual approach slope indicators (a) (d) Runway edge (d) Runway threshold (d) Runway end Obstacle (a)	15 seconds 15 seconds 15 seconds 15 seconds 15 seconds 15 seconds
Precision approach category I	Approach lighting system Runway edge (d) Visual approach slope indicators (a) (d) Runway threshold (d) Runway end Essential taxiway (a) Obstacle (a)	15 seconds 15 seconds 15 seconds 15 seconds 15 seconds 15 seconds 15 seconds
Precision approach	Inner 300m of the	1 second

category II/III	approach lighting system Other parts of the approach lighting system Obstacle (a) Runway edge Runway threshold Runway end Runway centerline Runway touchdown zone All stop bars Essential taxiway	15 seconds 15 seconds 15 seconds 1 second 1 second 1 second 1 second 1 second 15 seconds
Runway meant for takeoff in runway visual range conditions less than a value of 800 m	Runway edge Runway end Runway centre line All stop bars Essential taxiway (a) Obstacle (a)	15 seconds (c) 1 second 1 second 1 second 15 seconds 15 seconds

1.5 TRANSFER (SWITCH-OVER) TIME REQUIREMENTS

When the normal power source for critical visual aids fails, the load must be transferred to the standby power source. In the case of a local power source such as a diesel-electric generator unit, this source must be started, brought up to speed and the voltage output stabilized before the load can be transferred.

The "maximum switch-over time", is defined as the duration for the measured intensity of a light to fall from 50 per cent of the original value and recover to 50 per cent during a power supply changeover when the light is being operated at intensities of 25 per cent or above.



It is not the time for an electrical transfer to occur in the vault. As such the switch-over time is really an interruption time but of the light output rather than of the electricity. The time can be verified by a measurement of photometric output from a light in the field or a sample light installed in the vault. It is to be noted that with switch-over, the output of an incandescent light does not actually go to zero due to the thermal inertia in the lamp filament. This may not be the case for LED lighting for which inductance in the circuit may pay a more important role.

1.6 EQUIPMENT

1.6.1 Components

The components of the electrical power system should be of such quality that they will provide the reliability, availability, and voltages and frequencies needed by the facility. The major items of equipment commonly used for aerodrome lighting are engine-generator sets, power-transfer switching devices, to furnish power for starting the engine generators, and vaults or shelters for this equipment.

1.6.2 Engine-generator set

The basic secondary power source is an engine-generator set consisting of a prime mover, a generator, a starting device, starting controls, and a fuel tank. Engine generator sets for secondary power units are usually rated at 100 to 500 kVA capacity but may range from 50 to 1 000 kVA in capacity.

a) **Prime movers**. The prime movers for most secondary power units are gasoline, diesel, or gas engines or gas turbines, the choice being based on cost and availability of fuels. These prime movers are usually available in standardized sizes with adequate power to handle the kilovolt-ampere rating of the generator. The prime movers for most major aerodromes are rapid-start types which can start automatically, stabilize their speed, and be connected to the load within 15 seconds.

b) **Generators.** The generator, usually an alternator, is mechanically coupled to the prime mover and provides secondary electrical power at the frequency, voltage, and power rating of the unit. They may be either single-phase or three phase generators. They should have high efficiency in converting mechanical energy to electrical energy

c) **Starting devices.** Most secondary power engine-generator sets use battery packs to store energy for starting. Due to infrequent use, short operating periods, high starting current demands and cost, lead-acid type batteries are used most frequently for starting these units. The battery pack (often a set of batteries connected in series and/or parallel) must be capable of providing the voltage and current needed to start the engine within the required time limits and under the most severe conditions (usually at a low temperature of -7ºC) at which the secondary power unit is expected to operate. A battery charger with over-current and overcharge control is permanently connected to the electrical power to maintain the stored energy in the batteries. The battery pack should be well ventilated to prevent accumulation of hydrogen gas and should be protected from arcs, sparks or flames which could cause an explosion of any accumulated gas. Nickel-cadmium batteries may be used where special conditions warrant their high initial cost. Flywheels, pneumatic pressure vessels, other-than-battery stored-energy devices are used infrequently for engine starting because of unreliability or cost.

d) **Starting controls.** The controls for the engine-generator set are usually an automatic start with a sensor for primary power failure as part of the transfer switching device. Manual or remote controls are sometimes used for facilities with low critical requirements. Once it is started, speed and power are automatically regulated by the engine and the electrical load is connected by the transfer switch. The engine generator should operate automatically without adjustment or other attention. Transfer of power back to the public source and stopping the engine may be automatic or by remote control.

e) **Fuel supply.** Liquid fuel for IPU is usually stored in tanks near the engine generator location. The capacity of the fuel tanks should be adequate for the maximum operating time expected of the engine-generator. Some authorities require a minimum of 72 hours supply. Others design for a lesser time period but the time period usually should be at least twice the maximum duration expected of conditions that could require the use of secondary power. The facility is sometimes provided with an outside fuel tank and a smaller inside "day tank". Fuel tanks and connections should meet all safety requirements and should provide convenient access for refueling. These tanks should also provide arrangements for testing for contamination of the fuel, especially the accumulation of water in the tank.

1.6.3 Power transfer switching

A suitable transfer device is needed for transferring power from the normal supply to the standby supply. For manual starting and control this may be a simple switch or relay that disconnects the load from one power source and connects it to the other. Additional controls are needed for automatic transfer. These are usually combined into a single control unit or cubicle. Such a unit should be capable of sensing the failure of normal supply, initiating the starting of the standby unit, determining that the voltage and frequency of the generator have stabilized adequately, and connecting the load to the generator. This unit may also disconnect non-essential loads and facilities which are not to be energized by the standby supply and transfer these loads back to the normal supply after it has been restored. The switches or relays for disconnecting and connecting the load should have the capacity to handle the rated load of the generator. The functioning of these switches or relays is similar for either the 15-second, or 1-second transfer times, although more rapid-acting relays may be needed for the shortest transfer time. For a 15-second transfer, the sensors must respond in less than 3 seconds each because the quick starting engines need at least 10 seconds to start and to stabilize.

1.7 VAULTS AND SHELTERS FOR ELECTRICAL EQUIPMENT

1.7.1 Shelters

Most electrical equipment for airport lighting and other facilities is located in vaults or special shelters for protection from the weather and for better security. Substations for high voltage are usually outdoors while medium voltage distribution transformers are often placed on fenced transformer pads. Most electrical vaults are above ground and made of fireproof materials. Reinforced concrete for the floors and concrete, concrete or cinder block, and/or brick for the walls are materials commonly used in these vaults. The use of such materials reduces the hazard of electric shock, shorting of electrical circuits and fire hazards. Prefabricated metal structures are occasionally used as shelters for transformers and engine-generator sets. These vaults are used to house the power distribution and control equipment, secondary power equipment and the various devices used to provide power and control for the airport lighting systems. The vaults should be of adequate size to contain the necessary equipment without crowding and may be divided into rooms for better segregation of equipment and activities.

1.7.2 Location

Electrical vaults should not be located where they would infringe on obstacle limitation surfaces. The distances from the control tower to the vaults should be short enough to avoid excessive voltage drop in the control cables. The permissible length of these cables varies with the size of the cable, the control voltage and the types of control relays used. However, some of the longer control systems limit the length of

control cables to about 2 250 m. Vehicular access to the vaults in all types of weather conditions is necessary and minimum conflict with aircraft traffic is desirable.
The location should be convenient for connecting to the appropriate lighting circuits and facilities to keep feeder cable lengths as short as is practical.
The vaults should be isolated from other buildings and facilities to prevent the spread of fires or explosions, except the shelters for secondary engine-generator sets may be near the electrical vault to reduce cable length and size and to simplify the power transfer system.

Aerodromes with approach lighting systems may need separate approach lighting vaults for each approach lighting system. For major aerodromes, some authorities use a vault near each end of the runway or approach lighting system to more easily arrange for interleaving of the lighting circuits and to improve integrity of the systems.

In some States, the term field electric centre (FEC) is used. The term refers to the location at or near the centre of the airfield from which the length of feeder cables to the lighting loads would be minimum.

1.7.3 Special provisions

As special purpose buildings, electrical vaults may require special features to provide safety and reliable performance of the equipment. Some of these features are as follows :

a) **Ventilation.** Provide adequate ventilation to prevent transformer temperatures exceeding the values prescribed by the equipment manufacturers. Most of the electrical heat losses must be removed by ventilation; only a minor part can be dissipated by the vault walls. Some electrical codes recommend 20 cm2 of clear grating area per kVA of transformer capacity. In localities with above-average temperatures, such as tropical or subtropical areas, the grating area should be increased or supplemented by forced ventilation.

b) **Access.** Adequate access should be provided for repairs, maintenance, installation and removal of equipment.

c) **Drainage.** All vaults should be provided with drainage. When normal drainage is not possible, provide a sump pit to permit the use of a portable pump.

d) **Security.** Each electrical vault should be equipped to deter inadvertent or premeditated access by unauthorized persons. This security is necessary to prevent interference with equipment operation and to protect those persons from possible electric shock. Some methods used are barred and screened windows, heavy-duty metal doors with padlocks and security fencing.

e) **Vault lighting.** Electrical vaults should be well illuminated for use during day or night. This lighting is usually provided by interior lights of a size, type and location to provide good visibility in all areas. Poor visibility can increase the potential for accidents resulting in electrical shock or improper control and adjustments. The vault should be provided with emergency lighting that will be operational upon failure of the main power supply.

f) **Local communications**. Most electrical vaults should be provided with convenient and reliable communications to the control tower, other vaults and perhaps other facilities or offices. Special telephone or intercommunication systems may avoid outside interference with these circuits, but other dependable arrangements can be used.

g) **Electrical conduits**. Electrical vaults should be provided with a sufficient number of conduits and cable entrance accesses to avoid later modification of the structure to permit the installation of additional input or output circuits. These cables entrances are usually through underground conduits which may be connected to existing cable ducts, direct-burial cables, or unused conduits available for future expansion. Unused conduits should be plugged and conduits with cables should be sealed.

h) **Installations of equipment**. Arrange the equipment, especially the larger items such as regulators, distribution transformers, control panels and circuit selector or control devices, to provide a simple, uncluttered plan. This arrangement should consider safety, especially protection from high-voltage electrical connections, as well as access to the equipment and controls. The electrical circuits should also be arranged in a simple pattern wherever possible. Follow the applicable electric safety codes for installing all electrical circuits and controls.

CHAPTER 2

SOLID STATE TECHNOLOGY

2.1 INTRODUCTION

Aeronautical ground lighting (AGL) originally developed from the available technology. That is, roadway lighting utilizing series-type circuitry, incandescent (filament type) lamped fixtures, isolating (AGL) transformers and constant current regulators. The advent of solid-state technology is progressively revolutionizing AGL and at the same time bringing forth new issues. The purpose of this chapter is to provide a brief overview regarding design and maintenance.

2.2 LIGHT EMITTING DIODES (LED) LIGHT UNITS

Of the various forms of solid-state technology, that having light emitting diodes (LEDs) is most common for airports application. Initially LEDs were used for lights requiring relatively low levels of intensity such as obstacle lighting (32 cd) and taxiway edge lighting (2 cd). Over the past recent years, the efficacy of LEDs has improved to such a degree that this technology is now used for all types of AGL, including signs, high intensity edge lights, high intensity approach lights, runway guard lights

2.3 INFRASTRUCTURE — SERIES CIRCUIT

The typical infrastructure for airfield lighting with incandescent fixtures has been a series-type circuit having a constant current regulator, high-voltage cable, and a multiplicity of AGL transformers. The light units are connected to the low voltage secondary side of the isolating transformer. LED light units can be procured for simple placement into this circuit.

2.4 BRIGHTNESS SETTINGS

It is desired that a LED light unit should perform in the same manner as the incandescent light unit. the natural LED response to current input is linear as compared to that of an incandescent light whose response curve is exponential because it is the result of filament heating. For example, an incandescent light unit that is operated at 5.2 A should produce an intensity which is about 25 per cent of full intensity.

The LED light on the other hand, which operates at 5.2 A (input from the isolating transformer), would produce about 79 per cent intensity. If the LED light were to be driven directly so that it produces 25 per cent intensity, a current of about 1.6 A would be used. Note that the chart and current values relates to 3- and 5-step systems. Systems which have six or more steps would have different current values for each step.

The performance of the incandescent light can be defined in terms of the minimum/maximum range of the dimming curve as shown in Figure 12-10 for white light. The steps for a 5-step constant current regulator are 6.6, 5.2, 4.1, 3.4 and 2.8 A. For a 3-step regulator they are 6.6, 5.5 and 4.8 A. The dimming curves for incandescent lighting are displaced at 4.8 A and 5.5 A as reflects the historical development of 3-step systems.

In order to mimic the performance of the incandescent light, the algorithms of the electronic component of the LED fixture are such that the intensity output is within a minimum/maximum range which is near that of the incandescent light, with exception for the lower steps. The range is reduced for the lower steps because of reports that the LED light appeared to be too bright at these steps. The dimming curves for incandescent lighting are displaced at 4.8 A and 5.5 A to reflect the current/brightness values specified for 3-step systems. Note that the curves converge at 6.6 A. All lights, either incandescent or LED begin at 100 per cent and the curves are read from the top down.

2.5 MIXING TECHNOLOGIES

LED fixtures contain electronics to ensure that its response will mimic that of incandescent lighting. Yet even though the response is made the same, it is not recommended that LED and incandescent lighting be mixed, for reason that the LED fixture can produce a different visual display. In particular, the LED fixture produces a saturated color that remains essentially the same with brightness step selection whereas incandescent lighting will tend towards yellow as the filament is operated at a cooler temperature.

The following is a list of lighting facilities with respect to mixing LED and incandescent technologies:

a) Elevated runway guard lights (RGL). For individual installations, each pair of elevated RGLs on both sides of the taxiway should be of the same technology.

b) In-pavement runway guard lights (RGL). For individual installations, all the lights of an in-pavement RGL system should be of the same technology.

c) Stop bars. For individual installations all the lights of an in-pavement stop bar system should be of the same technology.

Note.— Where elevated supplemental stop bar lights are installed they should be of the same technology on both sides of the taxiway. However, they may be of a different technology than the in pavement stop bar lights.

d) Touchdown zone lights. For individual installations, all the lights of a touchdown zone lighting system should be of the same technology.

e) Runway centerline lights. For individual installations, all the lights of a centerline lighting system should be of the same technology.

f) Runway status lights (RWSL). For individual installations, all lights of THL (take-off hold lights), REL (runway entrance lights) should be of the same technology.

Note.— RWSL may be of different technology than the runway centerline or touchdown zone lighting on the same runway.

g) Runway edge lights. For each individual installation, all the lights of a runway edge lighting system including the yellow portion within the end of the runway caution zone should be of the same technology.

h) Runway threshold, end and stopway lighting. For each individual installation, all the lights of the runway threshold, runway end and stopway should be of the same technology.

Note.— The lights of runway edge, runway threshold, runway end and stopway lighting may each be of different technology from that of the associated runway centerline and touchdown zone lighting.

i) Signage. Per location, sign elements making an array of signs should be of the same technology.

j) Runway holding position signs. Per runway holding position location, signs on both sides of the taxiway should be of the same technology.

k) Intermediate holding position signs. Per intermediate holding position, signs on both sides of the taxiway may be of different technology.

l) Rapid exit taxiway indicator lights (RETIL). Per individual installation, the lights of RETIL should be of the same technology.

m) Precision approach path indicator (PAPI). Per runway end, the light units of PAPI should be of the same technology. This includes where PAPI are installed on both sides of a runway.

n) Approach lighting systems. Per runway end, the white steady burning lights of an approach lighting system should be of the same technology.

Note 1.— All the lights of RAIL of an approach lighting system should be of the same technology, but may be of a different technology than the white steady burning lights.

Note 2.— All the lights of Category II/III red supplemental lighting should be of the same technology, but may be of a different technology than the white steady burning lights.

Note 3.— All the lights of the green threshold and wing bar lighting of an approach lighting system should be of the same technology, but may be of a different technology than the white steady burning approach lights.

o) Taxiway lighting. Taxiway lighting per "segment" should be of the same technology.

Note 1.— A "segment" is defined as a taxiway portion delimited by intersections with other taxiways or runways and the tangential points of the start/end of curves.

Note 2.— In the case of long taxiways serving a runway and with many intersecting taxiways, it may be preferable that all segments are of the same technology.

Note 3.— Taxiway centerline and edge lighting within a segment may be of different technologies.