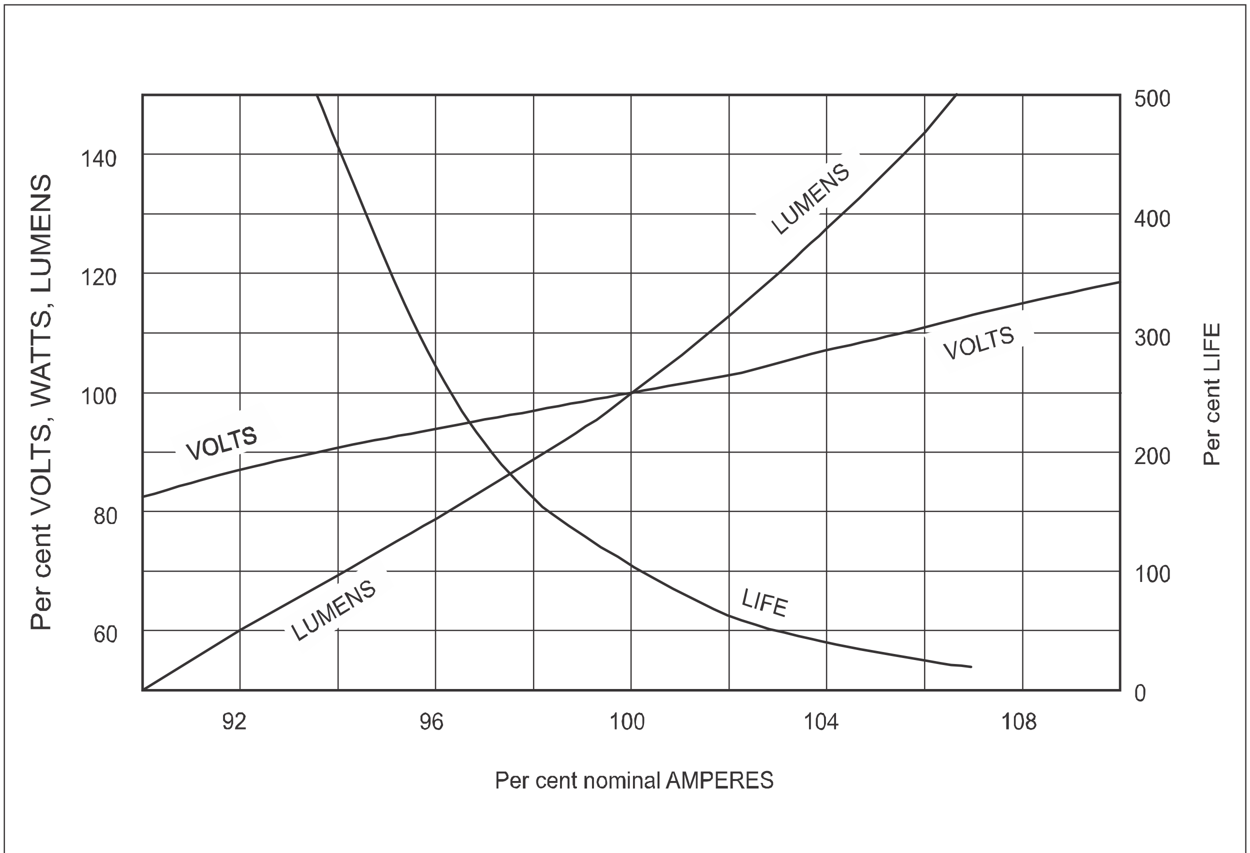

Figure 11-2. Effect of voltage variation on the operating characteristics of incandescent filament lamps in series lighting circuits (adapted from IES Lighting Handbook 1984)

11.1.3 The designer of an aerodrome lighting system may have some latitude regarding the choice of lamps for certain aerodrome light fixtures, selecting a series lamp, a low-voltage multiple lamp, or a higher-voltage multiple lamp. The following factors are pertinent in the choice:

a) the voltage drop across series lamps usually falls in the "low-voltage" category; the voltage drop across a 6.6 amperes, 200 watt runway edge light is 30 volts, and the voltage drop across a 20 amperes, 500 watt approach light lamp is 25 volts;

b) because of their differences in design tolerances, series lamps should not be used in parallel circuits and multiple lamps should not be used in series circuits; and

c) the life of a "low-voltage" lamp will be greater than that of a "high-voltage" lamp, for a given rated power consumption and light output.

Tungsten-halogen lamps

11.1.4 Many lamps now being used for aerodrome lighting are tungsten-halogen lamps. The filaments of these lamps are enclosed in small quartz tubes which contain small amounts of a halogen, such as iodine, in addition to the usual inert fill gas. When the filament is heated, tungsten evaporates from the filament and condenses on the inside walls of the lamp envelope. The vaporized halogen combines with this condensed tungsten forming a vapour. This vapour travels to the hot filament where it disassociates and redeposits the tungsten on the filament. This process reduces blackening of the lamp bulb, increases the life of the lamp, maintains better light intensity, and improves the efficiency of the lamp. The cost of the lamps is however increased. The halogen cycle works most effectively at the rated current of the lamp. For this reason, systems such as that of approach lighting should be operated at the highest brightness step for a suitable duration to limit blackening of the lamp envelope.

Infrared coated (IRC) lamps

11.1.5 Halogen lamps produce more than just visible light; 60 per cent of the radiated energy is unused infrared radiation. Some manufacturers may have available IRC lamps for their fixtures. This is a halogen lamp with a special coating on the filament tube or reflector which redirects infrared (IR) energy (heat) back to the filament so that the filament will operate at a higher temperature producing more lumens per watt, greater luminous efficacy, lower power consumption and longer life. In terms of lifespan, IRC lamps will last twice as long as standard halogen lamps under the same conditions.

11.1.6 Figure 11-3 shows an MR16 lamp with a multifaceted reflector (MR). The designation "16" is the outside diameter of the reflector in eighths of an inch. In as much as the photometrics of the light unit are dependent upon the lamp, airport operators should not change the type of lamp without acceptance by the light unit manufacturer.

11.1.7 The PK30 lamp (Prefocus, Kabel (wire), diameter of base in millimetres) as shown in Figure 11-4 is used in such light housing assemblies as PAPI and edge lighting. The small size of the lamp and filament allows better optical control. As for other aviation lamps, caution in handling is necessary due to the high level of heat produced.

11.2 GASEOUS DISCHARGE LAMPS

Sequence-flashing approach lights ("strobes")

11.2.1 The lamps used in the sequence-flashing approach lights are gaseous, capacitor-discharge lights and not incandescent lamps. The lamp is a tube which may be formed into various shapes containing an inert gas, such as argon or krypton, which emits light when an arc is created in the gas. The power supply charges electrical capacitors which are the source of energy for the arc and also provides the triggering voltage to initiate the arc. Very high voltages are present in the power supply and lamp and this hazard should be considered in the design of the lighting system. The peak intensity of the lights may be very great but of short duration. The frequency of the flash is limited by the time required to recharge the capacitors and is typically a few times per second.

Obstacle lights

11.2.2 In the case of obstacle lighting, a very short duration flash is not suitable for navigation guidance during night-time. If the flash is too quick, it becomes difficult for the pilot to locate the light against the dark surround of night-time environment. For this reason, the lights are designed so as to produce a quick sequence of pulses which are sufficiently close to each other so as to be seen by the pilot as a single long duration flash. The determination of effective intensity of such multiple pulse flashes is described in the *Aerodrome Design Manual* (Doc 9157), Part 4.

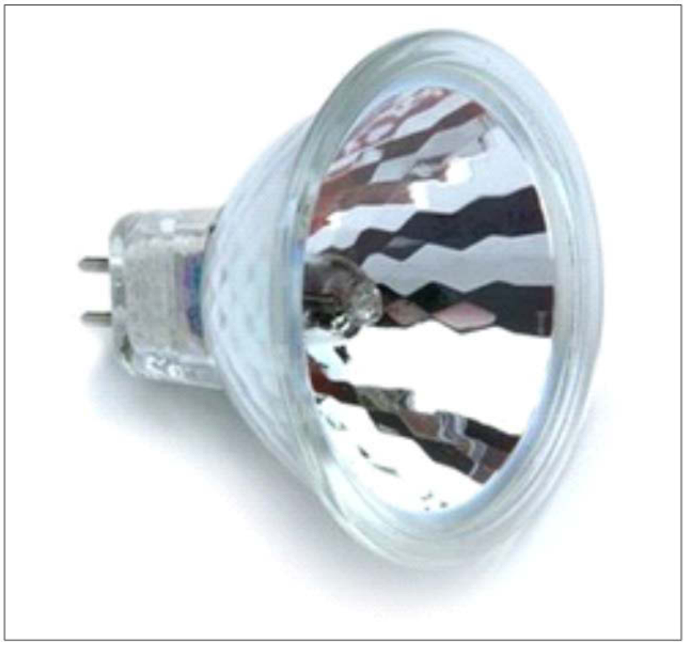

Figure 11-3. MR16 lamp with reflector (source: Genesis Lamp Corporation)

Figure 11-4. PK30 lamp (source: OSRAM GmbH)

Other gaseous discharge lamps

11.2.3 The higher efficiency of gaseous discharge lamps encourages their use. Types of these lamps include fluorescent, mercury-vapour, metal-halide, and low or high-pressure sodium-vapour lights. The use of lights of these types is usually limited to illumination of areas such as apron areas except for the use of fluorescent lamps in some taxiway edge lights and for illuminating signs. When considering using lights of this type, the following are factors that should be investigated:

a) *Restarting.* Some of these lamps cannot be restarted for several seconds to minutes after the arc is extinguished. Power interruptions or switching can cause loss of lights at critical times. Emergency lighting by other types of lamps may be desirable.

b) *Cold starting.* Some of these lamps cannot be started or are difficult to start in low ambient temperatures.

c) *Intensity control.* These lamps often are not capable of intensity control or have a limited range of control as compared to incandescent lamps.

d) *Stroboscopic effects.* The stroboscopic effects of the lamps may be disturbing. Where such lights are used, including for illumination of areas, the use of three-phase electrical supply systems with a balance in connecting the lights may be desirable.

e) *Colour shifting.* Typically the light emitted from these lamps covers a limited part of the visual spectrum. This makes recognition of colour coding difficult as colours may not have their ordinary appearance when illuminated by gaseous-discharge lamps. The colour "red" is particularly affected.

Chapter 12

SOLID STATE TECHNOLOGY

12.1 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.

12.2 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 (see Figure 12-1).

12.3 COLOUR — CIE S 004/E-2001

12.3.1 One of the advantages of LED light sources, in comparison to incandescent lighting, is that the colour of the output device is relatively stable with dimming. That is, the colour does not shift in chromaticity as the current is reduced for dimming. This has made possible the adoption of the CIE standard S 004/E-2001 "Colour of Light Signals" with some modification for the colour white (blue boundary). The Annex 14, Volume I, has two diagrams; Figure A1-1(a) for incandescent lighting (filament-type lamps) and Figure A1-1(b) for solid state lighting. The colour boundaries for incandescent lighting in Figure A1-1(a) are those of CIE 2.2-1975 "Colours of Light Signals". It is anticipated that eventually incandescent technology will be completely replaced by solid state technology and only Figure A1-1(b) for solid state lighting would remain in Annex 14, Volume I.

White and variable white

12.3.2 The AGL for approach, runway edge, runway touchdown zone and centreline are specified in Annex 14, Volume I, as being "variable white" in colour. The chromaticity boundaries are shown in Figure 12-2. "Variable white" is any colour from $x = 0.285$ up to the boundary of the yellow area of $y = 0.790 - 0.667x$ and is the range of whites that exist along the correlated colour temperature line or Planckian Locus from about 10 000 degrees Kelvin to about 1 900 Kelvin and includes the ICAO white, which ends at $x = 0.500$ following the specified boundary equations of Appendix 1. The Planckian Locus is representative of the colour change that occurs as incandescent lighting is dimmed and the filament takes on a more yellowish tinge as it is cooled to lower temperatures.

Figure 12-1. Types of LED lighting

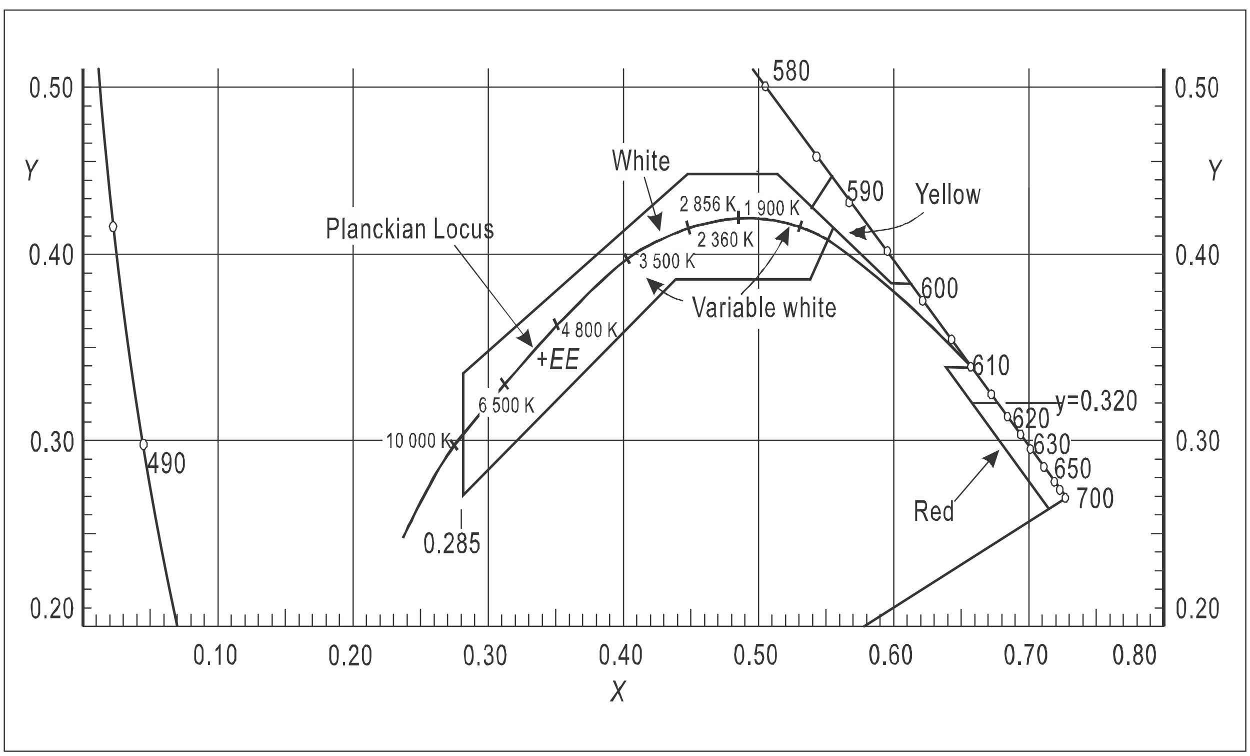

Figure 12-2. White and variable white for incandescent lighting

12.3.3 In the case of LED lighting whose colours are relatively stable with dimming, the specification for "variable white" is to be interpreted as "white" for which the colour boundaries are shown in Figure 12-3. The green and purple boundaries of white are the same as that for incandescent lighting. The blue boundary is moved to $x = 0.320$ to give further separation from blue. The yellow boundary is at $x = 0.440$ which is recommended by CIE S 004.

Yellow

12.3.4 The yellow for solid state lighting is that of CIE S 004 for which the green boundary is extended to $y = 0.727x + 0.054$ to include the ITE (Institute of Traffic Engineers) yellow.

Red

12.3.5 The red for solid state lighting is that of CIE S 004 and is the same as for incandescent lighting. Note that the red for PAPI light units continues to be limited to an upper boundary at $y = 0.320$ in accordance with Annex 14, Volume I, 5.3.5.14 and 5.3.5.30.

Blue

12.3.6 The blue for solid state lighting is approximately half that for incandescent lighting to give further separation from the bluish-green portion of the green chromaticity area.

Green

12.3.7 The green for solid state lighting is similar to that for incandescent lighting except that the white boundary is now the latter's restrictive white boundary ($x = 0.625\,y - 0.041$) to give better recognition from white. The blue boundary is changed to $y = 0.400$ to give better recognition from blue. The yellow boundary is straightened to $x = 0.310$.

12.4 LIMITING SELECTION FOR SHADES OF GREEN

The green chromaticity area is relatively large in comparison to that of other colours and contains a range of shades from yellow-green to blue-green separated by the restrictive boundary $y = 0.726 - 0.726\,x$. In order to avoid a too large variation of shades within the same lighting system, if the site selects lights having a green colour in the yellow-green portion of the chromaticity area, it is recommended that greens from the blue-green portion should not be used within the system and vice versa. This requires that airport design staff have a knowledge of colour specification.

12.5 INFRASTRUCTURE — SERIES CIRCUIT

12.5.1 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. As shown in Figure 12-4, the LED light unit is composed of ratio transformer, bridge rectifier and a converter which contains a microprocessor for control of the intensity of the LED. This figure does not show surge suppression components for lightning and transient protection.

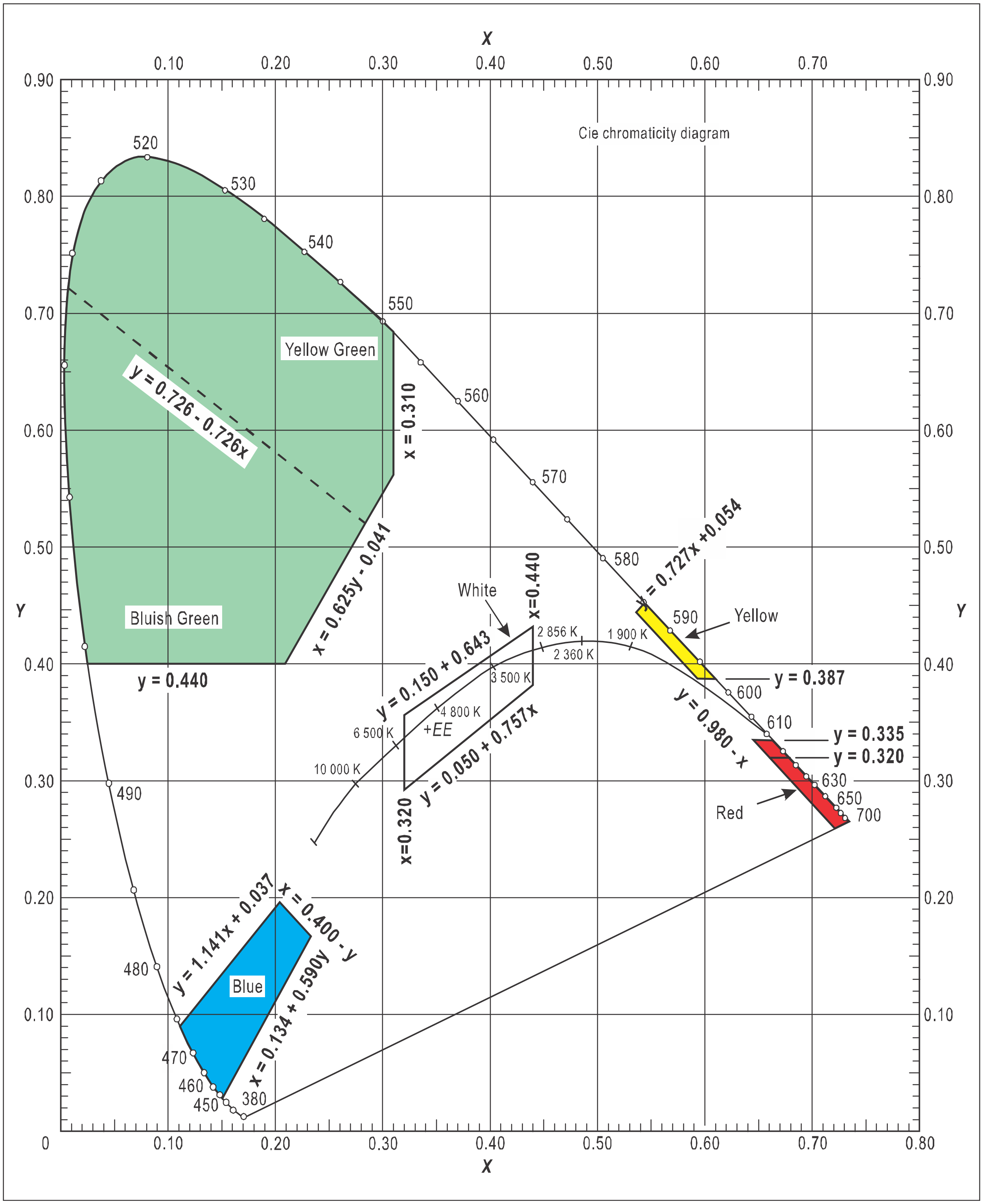

Figure 12-2. White and variable white for incandescent lighting

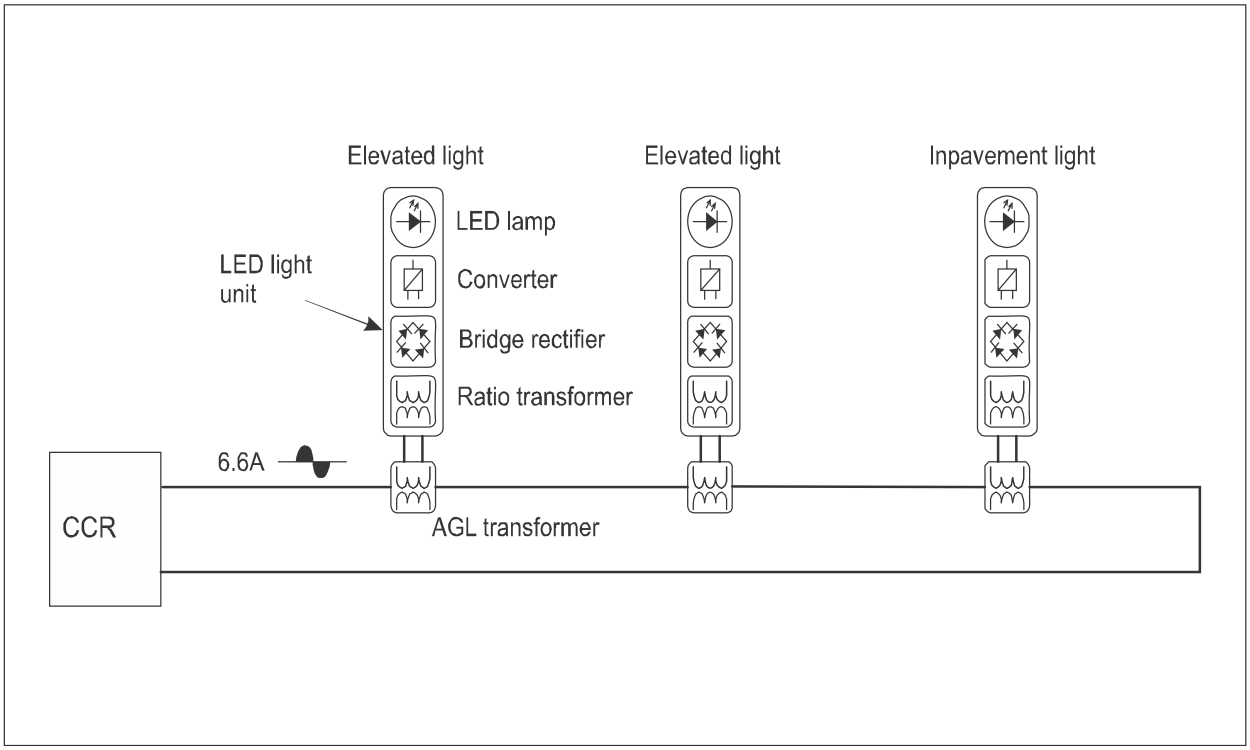

Figure 12-3. Chromaticity boundaries for solid state colours

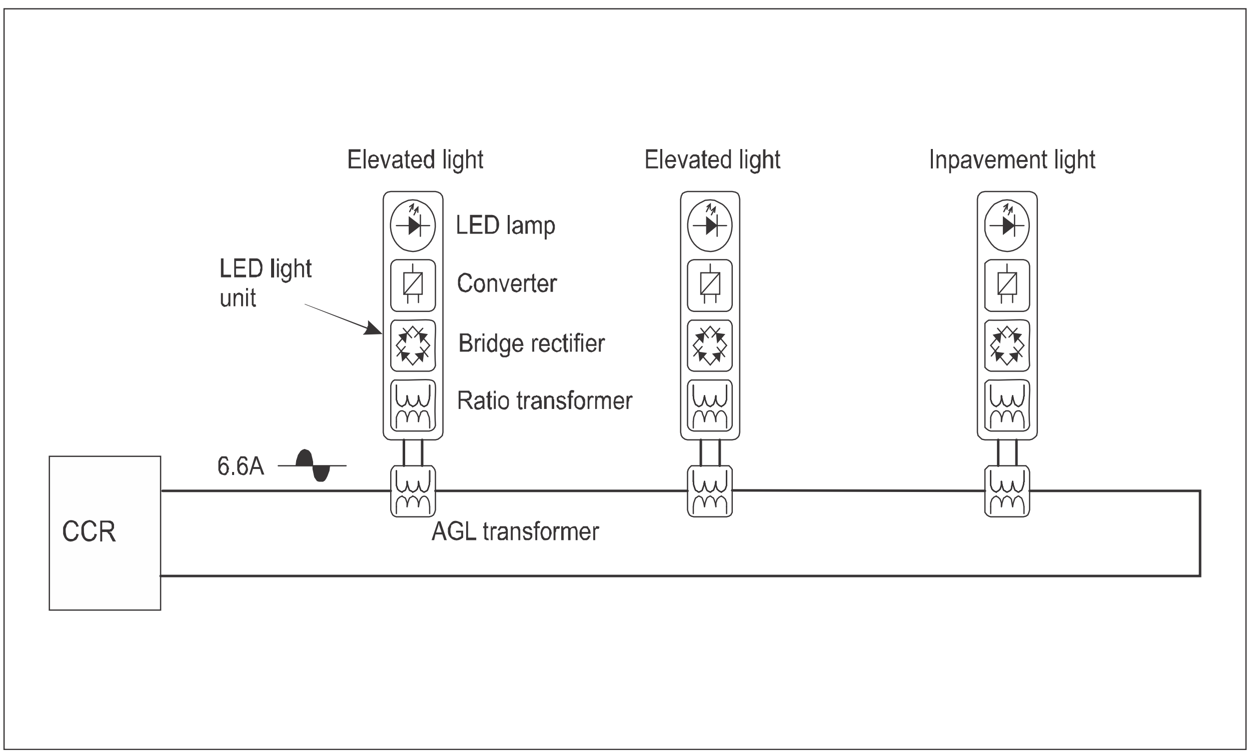

Figure 12-4. Series circuit LED lighting

12.5.2 The ratio transformer provides a current level (e.g. 660 ma) that is useable by the LED lamp. As an alternative, the function of the ratio transformer could be combined with that of the AGL transformer to have a single device with a turns ratio of 10:1.

12.5.3 The bridge rectifier changes the AC secondary current to DC.

12.5.4 Note that a by-pass device is not needed for either in-pavement or elevated LED lights since the constant current regulators are specified to operate properly when up to 30 per cent of the lights have open secondaries.

12.5.5 The electronic converter provides an input to the LED. In as much as it is desired to operate the LED at its nominal rating, the converter uses pulse width modulation (PWM) to cause a change of intensity. The algorithms cause the LED light to simulate the performance of a conventional incandescent lamped fixture (see 12.9).

12.6 PULSE WIDTH MODULATION

LED lamps are normally operated at their full nominal current. Intensity change (dimming) is accomplished through means of pulse width modulation (PWM). As shown in Figure 12-5, the input waveform is altered by changing the width of the pulses to produce high, medium and low intensities. The amplitude of each pulse is at the nominal rating of the LED lamp.

12.7 INFRASTRUCTURE PARALLEL CIRCUIT

LED lighting has also been applied using a parallel circuit design as illustrated in Figure 12-6. The components of the light unit are somewhat simplified. This circuit design has advantages of increased power efficiency and ease of control. There is also the advantage of simplification of maintenance practices and safety regulations for low voltage installations on the airfield side.

12.8 ALTERNATE INFRASTRUCTURE

12.8.1 Whilst the individual LED fixtures require considerably less electrical energy in comparison to incandescent lamped fixtures, with use of a conventional circuit there is still the energy consumption of CCRs and AGL transformers. Energy consumption of CCRs can vary with the type of architecture present in the CCR. For example, ferroresonant CCRs typically maintain good input power factor and efficiency when lower LED loads are substituted. However, SCR (i.e. Thyristor) CCRs typically impose almost the same load on the incoming power source when a lower load is substituted on its output. These CCRs typically have taps that can be adjusted to increase efficiency when lower loads are present. Also, AGL transformers can operate acceptably well if a lower LED load is substituted. However the AGL transformer will have its best efficiency if a lower wattage transformer is substituted that matches with the lower load of the LED fixture. Also, most CCR designs, particularly older models with incoming high-voltage transformers, have a fixed minimal charging current when energized, regardless of the connected load. Thus, the full economies possible with LED design are not actually taken advantage of. This raises the possibility of radically changing the lighting circuit design to some alternate infrastructure as shown in Figure 12-7.