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LEADERS IN LIGHTING TECHNOLOGY

South African Emergency Lighting Guide

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1. What is emergency escape lighting?

Emergency escape lighting can be defined as that part of emergency lighting provided during a power failure to allow for safe egress of occupants out of a building. The emergency lighting is only required to be bright enough for the occupants to find exit doors and avoid obstacles. Energy is usually provided by batteries whose capacity is sufficient to provide enough time for all the people to vacate the premises.

In terms of the Occupational Heath and Safety Act (OHS Act 85 of 1993), it is now mandatory to provide emergency lighting and so it is important that both South African building owners and the building industry are made aware of good practice for the design and cost effective implementation of emergency lighting systems. In addition, it is compulsory that any emergency lighting system installed satisfies strict performance and operational criteria (SANS 1464 Part 22)

Emergency lighting is usually tacked on as an afterthought because it is a safety requirement only and does not contribute in any way to building aesthetics or money making potential. Cost of implementation is therefore a serious consideration for initial installation, maintenance and upgrade potential – factors generally ignored in other wealthier countries.

This guide draws on both local practice and international guidelines to provide the following aspects:

- Emergency lighting categories
- Emergency lighting sources
- Emergency lighting system types
- Luminaire compatibility
- Batteries
- Measuring emergency lighting output
- Maintenance
- Common faults
- Design considerations
- Legal requirements

2. Emergency lighting categories

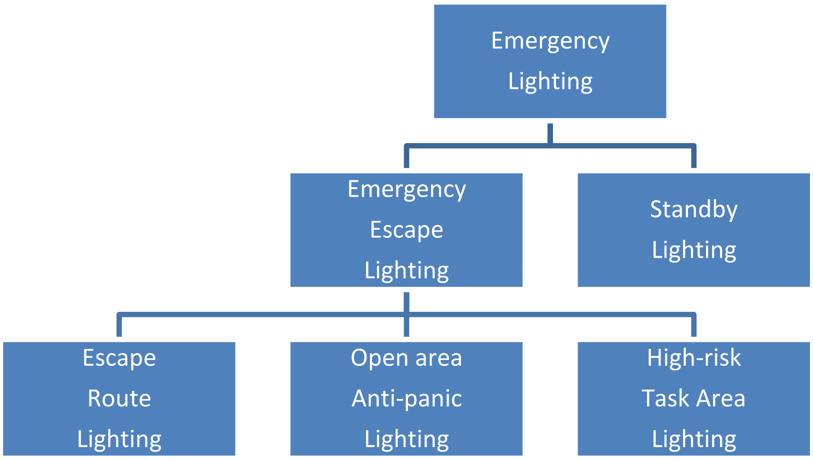


Figure 1

The above diagram shows the various categories of emergency lighting. Further details and explanations can be found in the analysis of SANS 0114-2 in chapter 17.

Emergency escape lighting: That part of emergency lighting provided to enable safe exit in the event of failure of the normal supply.

Standby lighting: That part of emergency lighting provided to enable normal activities to continue unaffected in the event of failure of the normal mains supply. These expensive systems provide full power to all lighting are not required by law for general lighting and is therefore not considered here.

Escape route lighting: That part of emergency lighting provided to enable safe exit for building occupants by providing appropriate visual conditions and direction finding on escape routes and in special areas/locations, and to ensure that fire fighting and safety equipment can be readily located and used.

Open area anti-panic lighting: That part of emergency escape lighting provided to reduce the likelihood of panic and to enable safe movement of occupants towards escape routes by providing appropriate visual conditions and direction finding.

High-risk task area lighting: That part of emergency lighting provided to ensure the safety of people involved in a potentially dangerous process or situation and to enable proper shut down procedures to be carried out for the safety of other occupants of the premises.

3. Light sources for emergency escape lighting

This chapter describes lamps and light sources that are suitable for use in emergency lighting systems and whether emergency lighting products are available to suit. The light levels needed for emergency escape are low and therefore lamps are not usually required to run at full power. An advantage is that system cost is also lower at low lamp powers – a very important aspect. However, low power may be detrimental to some lamps and sometimes lumen efficacy (efficiency in turning power into visible light) is also adversely affected. For emergency lighting systems powered by standby generators or Uninterruptible Power Supplies (UPS), no restrictions on lamp type apply because the lamps will receive full power in emergency mode.

Not covered here are the photo-luminescent (glowing) type exit signs because they are very rare in this country.

3.1. Incandescent lamps

Normal 230 V GLS incandescent lamps are not really suitable for emergency lighting and are seldom used these days. The main reasons for this are that their lumen efficacy is very low (they produce more heat than light) and that dimming only aggravates the situation.

Low-power krypton lamps are still being used in some exit signs operating at full power. This is a cheap solution for a non-maintained exit sign but popularity seems to be waning.

Halogen lamps are still very popular for general lighting especially in downlights. They are favoured even though, again, they produce more heat than light, but low voltage types (12 V) can be easily and cheaply operated from battery power in emergency mode even if the lamp is used in a dimming circuit. Very little damage is caused to the lamp when operated at low power and there is negligible damage caused when the lamp is run at full power in emergency mode. It is not feasible to run any incandescent lamp at very low power (less than 50%) because no visible light will be produced, only heat. Emergency lighting products for low voltage halogen lamps are readily available.

230 V ac Halogen lamps are not suitable for use with self-contained emergency circuits.

3.2. Fluorescent lamps

T8 Fluorescent lamps take the lion's share of industrial lighting because they are now the most cost effective means of turning power into light. Many emergency products are available to drive the full range of linear fluorescent T12 and T8 lamps. The lumen efficacy of fluorescent lamps is not dramatically affected at low lamp powers – a fact that also contributes to their suitability in the emergency role. Lamp life is, however, severely reduced by all currently available emergency products especially those that run the lamp at very low power. This is an important consideration when testing the emergency lighting system because excessive testing will destroy the lamps. The reason for this phenomenon is that fluorescent lamps require external cathode heating when run at low power (dimmed) and no currently available emergency lighting products provide continuous cathode heating (for linear lamps). Products are available for use with electromagnetic ballasts, electronic ballasts and dimming circuits. The light output during emergency mode (Ballast Lumen Factor – BLF) is usually about 20% of full power (36W T8), being sufficient for most escape route lighting applications.

T5 fluorescent lamps are becoming increasingly popular due to higher lumen efficacies than T8 lamps but their electrodes are more fragile than those of T8 or T12 lamps and the lamps are prone to mercury electrophoresis when run in emergency mode. This means that they are more prone to lamp damage in emergency circuits and that colour shift (they turn pink) may occur in emergency mode although this effect recovers when powered by mains again. Many emergency products are available for all ballast types.

Compact fluorescent lamps (CFL's) are becoming increasingly popular for a vast range of lighting applications. Lamp wattages now range from 5 to 125 W and there are many different shapes and voltages. Of interest to our market are:

- Four pin types that basically behave the same as their linear counterparts
- Two pin types that have built in starters
- 12 V dc lamps that have internal ballasts
- 230 V ac mains types that have mains internal ballasts

Emergency lighting products are available for all four pin CFL's, including the new range of high power PL-H lamps with powers from 60 to 120 W.

Emergency gear is available for two pin CFL's with the proviso that operation must be possible in non-maintained mode.

12 V dc lamps are becoming increasingly popular in off grid applications and their availability now makes them ideal for emergency lighting

applications. Emergency lighting products designed for 12 V halogen lamps can also be used with 12 V dc CFL's.

230 V ac CFL's are not suitable for use in emergency lighting applications as they cannot be dimmed.

PL-T type, amalgam controlled, lamps (PLT 42 W, etc) have fragile electrodes and long warm up times if operated from traditional emergency control units. Specialised starting and boost warming phases are required to both prevent lamp damage and to ensure rapid light output stabilisation in emergency mode.

3.3. High Intensity Discharge (HID) lamps

HID lamps such as High Pressure Mercury Vapour (HPMV) and High Pressure Sodium (HPS) and Metal Vapour (MV) are not suitable for emergency lighting use unless run at full power. Another problem with these lamps is that they have a long warm up period and so, if used in emergency escape lighting, there will be a long period of darkness after a power failure, unless powered from an Un-interruptible Power Supply (UPS), (see Chapter 4.4).

3.4. Light Emitting Diodes (LED's)

LED's are currently used for accent and mood lighting as their cost per lumen still precludes their use for general lighting. Some designs, however, use strips of LED's as directional strips along passages etc where their use in emergency escape lighting is possible. In all LED lighting configurations standardised dc voltages are used *i.e.*, 12 V, 24 V, etc. and so current emergency lighting products of relevant outputs can be used. LED's do not suffer any damage when dimmed and their lumen efficacy is very high so they lend themselves for use in emergency lighting.

4. System types

There are many different system architectures to provide emergency lighting ranging from the humble hardware store type emergency light to complex central computer controlled systems. It is important to be aware of the locally available architectures in order to satisfy customer's requirements. Self-contained or stand-alone systems are by far the most popular because of their cost.

4.1. Self-contained emergency luminaires

These are luminaires with built in batteries that provide emergency light during a power failure and then automatically re-charge their batteries when mains is restored. They require a permanent mains connection to charge their batteries and to detect a mains failure. During a power failure, the control unit disconnects the lamp from the mains ballast (if fitted) and then powers the lamp from its internal battery pack. Most commercial luminaires can be modified by a professional lighting company into emergency lighting luminaires by installing the appropriate emergency control unit and batteries, re-routing the wiring and affixing the appropriate labels (see Figure 2). The minimum functional requirement (for compulsory requirements see Chapter 18) of self-contained emergency luminaires is that:

- They charge their own batteries
- A "battery charge" indicator lamp is provided
- They automatically provide light during a power failure
- They display the appropriate labelling

Figure 2

The table below shows typical relative light outputs, current drain and durations of an emergency control unit. Note how the relative light output (BLF), battery drain and duration vary with lamp type:

LAMP TYPE	LIGHT OUTPUT (BLF)	BATTERY CURRENT	DURATION (hours) 5x2Ahr (5x4Ahr)	VERSION
T12: 65 W	13%	1.1 A	1.8 (3.6)	33
T8 : 58 W	15%	1.2 A	1.7 (3.3)	33
T12 : 40 W	17%	1 A	2 (4)	33
T8 : 36 W	20%	1.1 A	1.8 (3.6)	33
T12 : 20 W	41%	1.1 A	1.8 (3.6)	10
T8 : 18 W	44%	1.1 A	1.8 (3.6)	10
T5 : 8 W	71%	0.9 A	2.2 (4.4)	10
TC-DEL: 26W	27%	1A	2 (4)	33
TC-DEL: 18W	30%	1A	2 (4)	33
TC-DEL: 13W	38%	0.8	2.5 (5)	33
TC-DD : 16W	38%	1A	2 (4)	33
TC-DD : 26W	25%	1A	2 (4)	33
TC-L : 18W	38%	1A	2 (4)	10
TC-EL : 9W	58%	0.9	2.2 (4.4)	10

4.1.1. Pros and cons

Pros:

- Low procurement and installation cost
- Readily available from numerous suppliers
- Flexible: It is suitable for both large and small installations
- Stand alone feature ensure system integrity
- Easy conversion of (most) existing luminaires

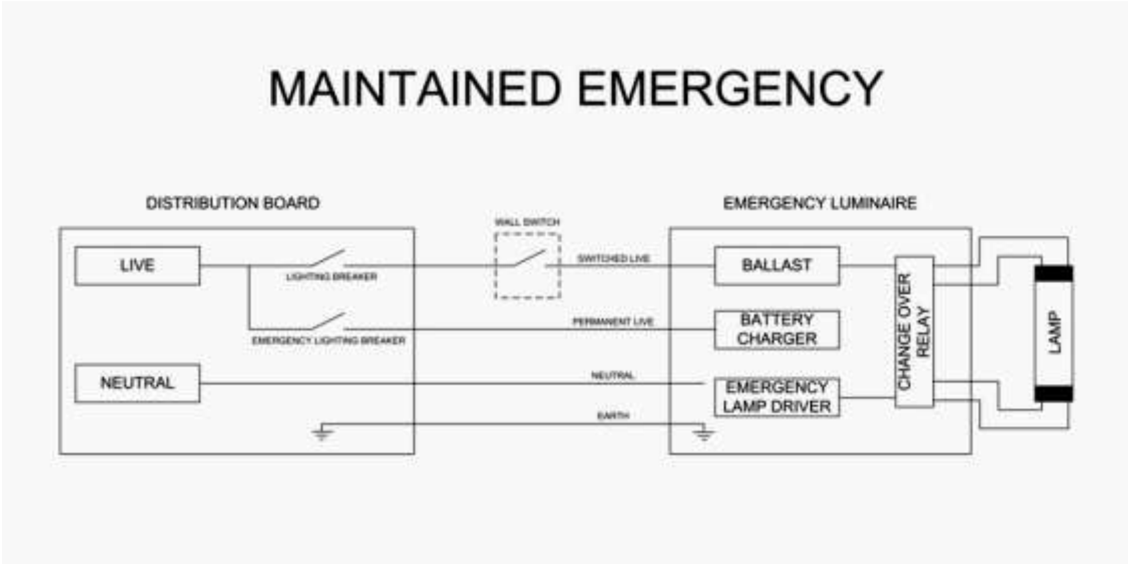
Cons:

- Battery replacement can be an issue making maintenance expensive
- Luminaire heat reduces battery life in many cases

4.1.2. Self-contained emergency operating modes

There are three main different types of operation:

- Maintained
- Non-maintained
- Sustained

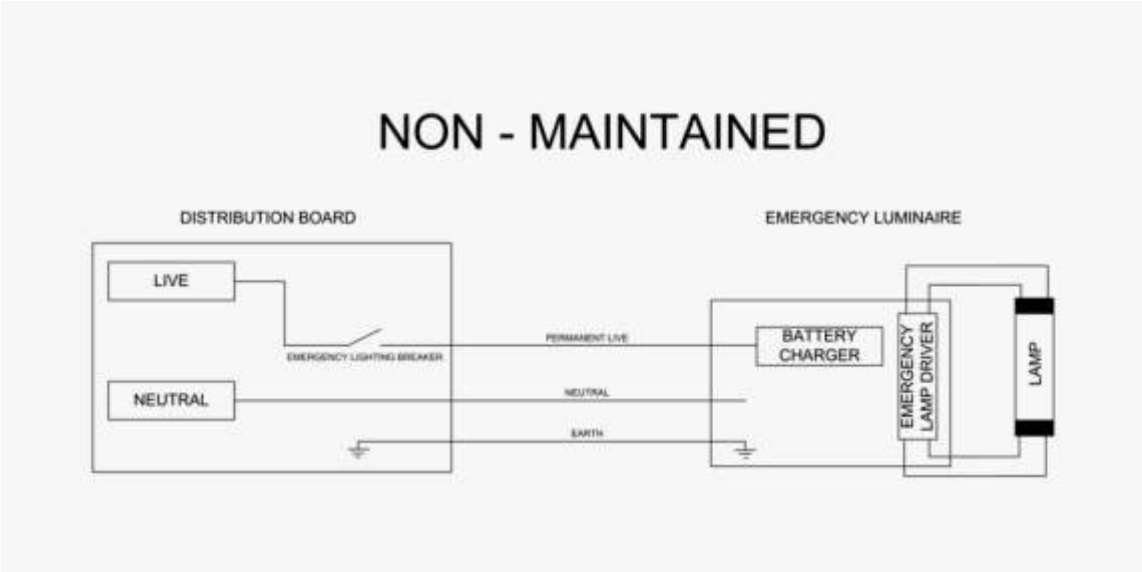


Maintained
A maintained luminaire can be used to provide both normal and emergency lighting. It has two mains connections: permanent live and switched live. The permanent live connection is used to charge the batteries and detect a power failure. The switched live is used to switch the light on and off to provide normal lighting.

A maintained emergency luminaire may contain more than one lamp for normal lighting but usually only one lamp illuminates during a power failure. This is a so-called combined emergency luminaire.

Maintained emergency luminaires are ideally suited for emergency lighting in:

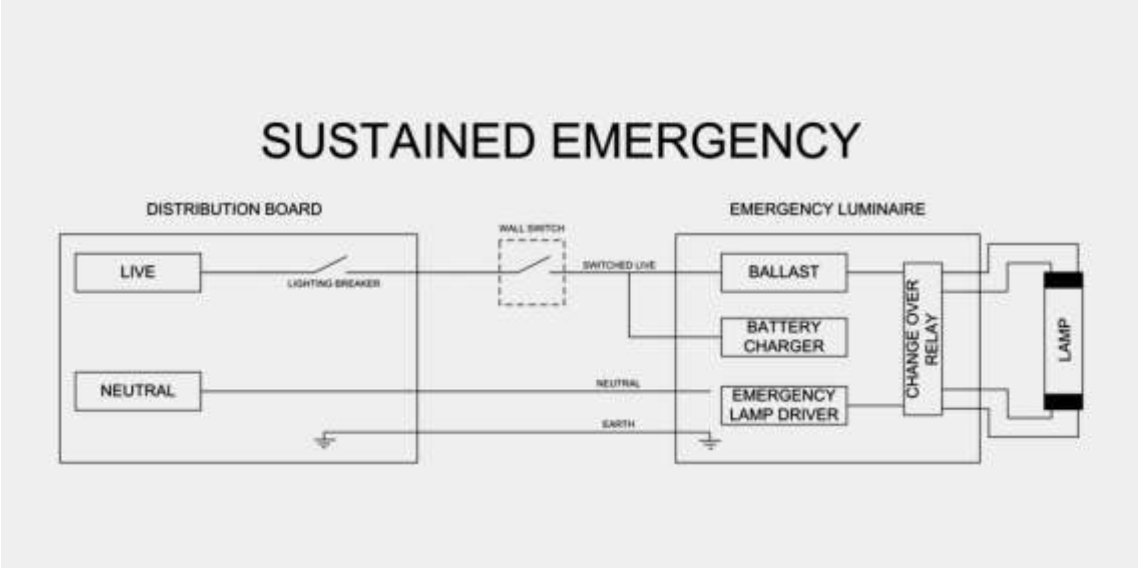
- Stair wells
- General office lighting
- Exit signs
- Escape route lighting
- In areas where it is preferable to merge emergency lighting into existing (or prospective) luminaires
- In new installations where the additional wiring requirements (the permanent live connection) can be readily accommodated.



Non-Maintained
A non-maintained emergency luminaire can only provide emergency lighting. It has only one mains connection that must be left on permanently. This connection is used to charge the batteries and to detect a power failure.

Non-maintained emergency luminaires are usually used:

- In areas where it is not possible to merge the emergency lighting gear into the existing luminaires. This situation is typically encountered in, for example, restaurants where the lighting may be of a decorative nature and be unsuitable for conversion in emergency luminaires.
- For high-risk task area lighting where bright, direct lighting is required during an emergency.
- For applications where the designer feels that the lamp depreciation of normal lighting must not affect the performance of the emergency lighting.
- For area flood lighting where the existing lamp is not suitable for use in an emergency lighting application.
- For existing lighting installations where it is not feasible to change the building wiring and the lighting is on permanently.



Sustained

Sustained fittings generally have two different set of lamps incorporated into the fitting. One set of lamps is used as the normal lighting and the other is reserved for use in an emergency. This gives the assurance that the emergency lamps will function when needed, as they have not been in service for a possible great length of time as in the maintained luminaire.

A South African adaptation of a sustained emergency luminaire is often used in stairwells where a maintained emergency luminaire is used with the permanent live and switched live bridged together. This method greatly simplifies building wiring (the switched live has usually already been routed to all the luminaires) but has three drawbacks:

- The switched live (wall switch) must be left on permanently.
- The lamp burns permanently and therefore has a low service life.
- The fitting runs hot continuously and so battery life is reduced.

4.1.3. Self-contained functionality options

Figure 3

Self-contained emergency control units (see an example in Figure 3) are normally offered with either one-hour or three-hour emergency durations. Many options of control unit are available to drive most fluorescent lamps with features designed to improve functionality or reduce maintenance costs. These include:

High power output

In some applications, the normal 20% BLF may be insufficient to provide floor illumination from high ceiling heights and for high-risk task area usage. Products have therefore been designed to provide BLF's of 50% and 100% (full power) light output in emergency mode. It should be stressed however, that these products are more expensive because they require larger battery packs (see Chapter 6), high power chargers and high power drive circuitry. A new range of products provides still higher powers from the 125W PL lamp for use as hi-bay emergency lighting.

Standby switching

Most emergency lighting products turn on immediately they detect a power failure causing unnecessary battery drain if the power failure occurs during the day. This problem is particularly troublesome in unmanned buildings such as sub-stations because by the time personnel arrive the batteries are flat. In such applications, an emergency system with a standby switch enables the emergency lighting to be switched on and off only when required thereby conserving battery power.

HID re-strike lighting

The inherent re-strike delay of HID lamps can be catered for with emergency lighting systems that not only provide lighting during power failures but also for a few minutes thereafter.

Self-test facility

These systems have built-in computer chips that enable self-diagnosis and reporting. This feature drastically reduces maintenance costs because no manual emergency lighting tests are required. The only effort required is a three monthly cursory glance at each emergency fitting to ascertain if any faults have been discovered. The fitting will report, by a flashing code or buzzer, the nature of the fault and then the technician simply has to replace the lamp or the batteries. New, high technology systems have advanced the art by providing an infrared communication ability to interrogate the fitting to access test data. The table below shows typical codes flashed by the indicator light to identify various states:

FAULT TYPE	LED CODE		BUZZER
Mains is on and the system is OK	No flashing, LED continuously burning	●●●●●●●●	Off
Battery voltage low	Continuous flashing	●○●○●○●○ 🔊	Beep every hour
Battery voltage too high	Three flashes followed by a pause	●○●○●○○○ 🔊	Beep every hour
Low capacity battery	Two flashes followed by a pause	●○●○○○○○ 🔊	Beep every hour
Lamp fault	One flash followed by a pause	●○○○○○○○ 🔊	Beep every hour
Battery & lamp fault	Long flash followed by one short flash followed by a pause.	●●○●○○○○ 🔊	Beep every hour
No mains	LED off	○○○○○○○○	Off

Figure 4

Figure 4 shows and infrared communication control unit being interrogated by a user. The luminaire responds by flashing codes on its indicator lamps and via chirps from its buzzer. This system further reduces maintenance effort and improves system flexibility via the two-way interface.

Features include forcing the unit to perform a self-test, standby operation, disabling the buzzer and determining how many tests have been performed.

The table below shows the control features via a standard M-NET type remote control:

Button	***Function***
(P-)	Suspend Emergency operation – conserve battery
(P+)	Turn Emergency back on if suspended
⓿	Perform a system reset (Bypasses commissioning test)
❶	Perform a quick test (2-minutes)
❷	Perform a half hour self-test
❸	Perform a one-hour self-test
(EXIT)	Stop a currently running self-test
(♬)	Disable hourly Buzzer - beep
(OK)	Report the number of automated tests performed since the last system reset

Photocell standby
These emergency lighting fittings have a built-in photocell that switches the light on only if the ambient light levels are low. This feature is especially useful in areas that experience long outage periods and ensures that emergency light is only provided at night.

Five pole switching
A simple method often used to test emergency lighting is to switch off the permanent live feed without switching off the switched live. This practice ensures that normal lighting is not interrupted whilst forcing the emergency lighting into emergency mode but may also cause ballast or control unit damage (see Chapter 8). To enable this practice and prevent damage special emergency products have been designed that feature multiple lamp and ballast switching protection.

4.2. Central battery emergency lighting systems

These systems consist of a central battery station and satellite emergency luminaires (see Figure 5). The satellite luminaires may be connected for either maintained or non-maintained operation. During a power failure, the central battery station provides emergency power (usually dc voltage from 12 to 110 V) for the satellite luminaires. This concept dramatically simplifies the problem of battery replacement that plagues self-contained types and facilitates an installation of distributed emergency lighting luminaires that often challenges the installation cost of self-contained units. Two main issues may complicate the installation of any central battery system. The first is that dedicated wiring with a low voltage drop and, in some cases, with flame retardant properties is required. The second issue is that the system cannot span multiple mains circuit areas (*i.e*., each with their own distribution board) because the emergency lighting is required to function during the failure of any mains circuit.

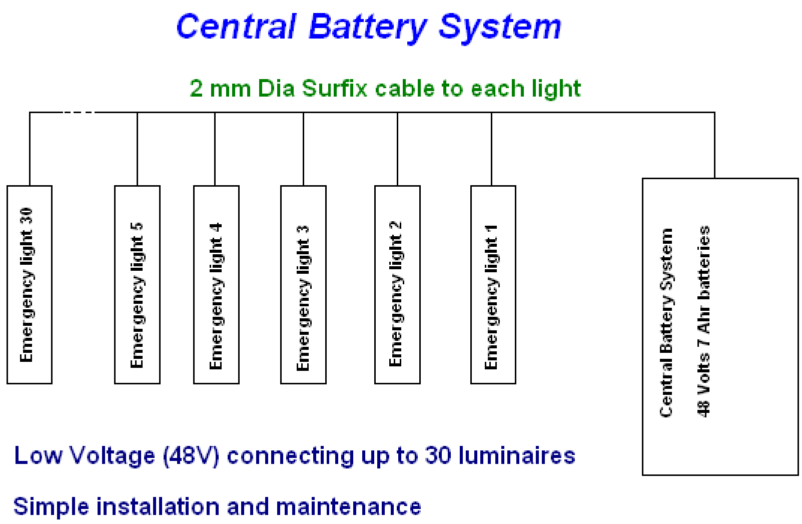


Figure 5

4.2.1. Pros and cons

Pros:

- Single battery radically reduces maintenance labour costs
- Potentially greater battery replacement periods as batteries operate at room temperature
- Lowest system cost with small non-maintained installations

Cons:

- Building wiring costs are greater especially if flame retardant cabling is used
- Cable voltage drop is an issue
- Must be configured to operate during any circuit failure

4.3. Generator sets

A generator set consists of an internal combustion engine that drives an alternator to produce mains (230 V ac). Generator sets are gaining popularity in South Africa especially after warnings from Eskom of impending power shortages until future scheduled power stations come on line. Ideally, the installation of a backup generator will enable normal activities to continue during power failures (stand by lighting) thereby satisfying emergency lighting legislation. Sets are available from kilowatt to megawatt ranges with features such as auto start and auto changeover. The problem with smaller units is that their output voltage is not well regulated which means that over-voltage conditions can occur resulting in luminaire ballast or lamp damage whilst under-voltage conditions (usually during high loading) may result in lighting malfunction. These potential conditions are particularly important to bear in mind when generator sets connected to luminaires with electronic control gear. The main problems with generator sets are that are their high initial cost and complex maintenance procedures as well as the fact that if the generator fails then there is no lighting – an important consideration.

4.3.1. Pros and cons

Pros:

- Enables normal activities to continue during power failures
- Simple wiring and installation
- No dedicated emergency lighting luminaires required
- No batteries required
- Low distortion waveform

Cons:

- Start-up delay period
- Must be configured to operate during failure of individual circuits – complex and expensive to engineer
- High power required to drive lighting at full power
- Expensive
- Complex maintenance procedures
- Noise
- Exhaust gases are toxic

4.4. UPS Systems

An Uninterruptible Power Supplies (UPS) is a battery powered power supply that provides mains during a power failure and is engineered to ensure no dead period between transitions. They were initially designed for computers to prevent unsaved data loss during mains and their wonderful, seamless supply of mains power ability has, in some installations, been extended to provide emergency lighting. It must be stressed that this is, however, a very expensive solution to a, potentially low cost, lighting problem. Their main engineering drawback for use in an emergency lighting installation is the extremely poor utilisation of stored energy as battery power is wasted at many conversion levels. There is power loss in generating the mains voltage, in the lamp ballast and the unnecessary, and unavoidable, driving of lamps at full light outputs during power failures.

4.4.1. Pros and cons

Pros:

- Provides an uninterrupted supply, especially important for computers
- Seamless transfer of power – Grid failure may not even be noticed
- Simple wiring
- No dedicated emergency lighting luminaires required

Cons

- Very expensive and prohibitively so for large installations
- Difficult to configure for failure of individual mains circuits
- Hugely energy inefficient for emergency lighting purposes because light fittings run at full power
- Cheaper versions have distorted waveforms

5. Luminaire compatibility

All too often, the emergency lighting requirements are tacked on at the end of any lighting design and treated as a necessary evil. This attitude causes many problems. Firstly, the very cheapest solution is sought with little or no consideration given to maintenance or support. Secondly, luminaire compatibility is seldom considered resulting in poor system reliability. Luminaire compatibility is especially important when converting normal luminaires into self-contained emergency luminaires where sometimes the emergency gear is crammed into the luminaire. Incompatibility can, and often does, result in:

- Non-conformance to standards and therefore illegal
- Poor reliability due to high luminaire temperature
- Maintenance complications because batteries may be inaccessible

Heat is the major factor influencing reliability because it degrades both emergency control unit reliability and battery life – battery life being extremely sensitive to temperature, including “high temperature” types. This chapter analyses common, commercially available, luminaires that are often converted into self-contained emergency units. Usually only one lamp of a multi-lamp luminaire is powered in emergency mode.

Figure 6

Figure 6 shows various self-contained emergency luminaire configurations using a surface decorative luminaire. Note that in all cases the emergency gear is positioned as far as possible from the ballasts.

5.1. Recessed fluorescent luminaires

These luminaires are extensively used in office areas and shops. They therefore represent the bulk of industrial applications for conversion into emergency fittings. The luminaires are designed mainly to house either 3 x 36 W T8 lamps or 4 x 18 W T8 lamps. The body depth is limited to the space required to contain the lamps and diffuser and they are usually no ventilation holes in order to prevent the ingress of dust and dirt. This means that the temperature within the luminaire will be hotter than room temperature and this is exacerbated by the use of switch start ballasts. Newer designs for T5 lamps are shallower and internal temperatures are even higher for two reasons:

- Smaller luminaire dimensions mean less heat dissipation
- T5 lamps are designed for a peak lumen efficiency at 35^0C versus 25^0C for T8 lamps

Care should therefore be exercised in positioning the batteries within the luminaire where they will be coolest. Ideal battery placement is on top of the luminaire in the ceiling cavity. Here the batteries will run significantly cooler thereby extending their service life. If they are positioned at the top edges of the luminaire then battery replacement is also simplified.

Virtually any self-contained control unit type can be accommodated in these types of luminaires but the one complicating issue is the placement of the indicator lamp. The indicator lamp must be visible without having to remove the diffuser to simplify maintenance.

5.2. Surface mount fluorescent luminaires

This includes both surface mount decorative and channel types. Surface decorative fittings are used where there is no ceiling to accommodate a recessed luminaire. Internal temperatures are similar to those in recessed luminaires but the problem is that batteries cannot be mounted outside the body without upsetting the aesthetics. Channel types have traditionally been a headache for luminaire conversion, especially two lamp high power types (2 x 36 W and 2 x 58 W) with switch start gear. The cannel (centre cavity) is designed to house only the ballast and wiring, and little else. With switch-start gear, this cavity temperature can rise to temperatures that severely reduce battery and control unit life. Some manufacturers include ventilation slots that reduce the temperature somewhat. Caution should therefore be observed when positioning gear within these luminaires.

Internal space is an issue with smaller lamps such as 2 x 18W T8, but virtually any self-contained control unit type can be accommodated in these types of luminaires.

5.3. Halogen downlighters

Halogen downlighters seem to be the vogue with architects for aesthetic reasons. Perhaps they are pretty but they offer little else in engineering terms, as their lumen efficacy is very poor (a small of the power they consume is converted into light). They are used extensively in reception areas and as general lighting and so, there is a requirement to convert some luminaires into emergency units.

There are three main configurations are:

- Concrete slab box (fitted into the concrete slab)
- Down lighter in suspended ceiling
- Protruding accent halogen lights

To accommodate downlighters in a concrete ceiling, a so-called concrete slab box is cast into the ceiling slab. The temperatures inside these slab boxes, especially with electromagnetic transformers, are extremely high and therefore unsuitable for emergency lighting gear.

Downlighters in suspended ceiling cavities can easily be converted into emergency fittings owing to the, usually, generous space available. It is, however, again important to keep the gear well away from heat sources such as the lamp and ballast. Emergency gear options include gear that is slim enough to be fed through the down lighter cutout into the ceiling cavity.

Protruding accent halogen lights always present a challenge if emergency gear needs to be fitted because of limited space within the luminaire. In most cases, a remote box must be added to house the emergency gear.

Figure 7 shows a common, self-contained, non-maintained, halogen emergency luminaire that can be used in areas where the existing or proposed halogen downlighters are not suitable for emergency conversion. Often, an issue with such solutions is aesthetics and so it is important to consider the location of such solutions with the architect or building developer at an early stage.

Figure 7

5.4. Pendant or suspended type luminaires

Very little room is usually available in these fittings for the addition of emergency gear necessitating the positioning of the emergency gear in the ceiling cavity. This is not a good solution because the wiring between the ballast and the emergency gear has to be extended back and forth between the luminaire and the ceiling causing a visual mess and compromising the performance of the emergency gear.

It is therefore usually best to use additional non-maintained emergency luminaires positioned strategically (to provide required lighting levels and to be unobtrusive) around the room. This can pose a problem where the room aesthetics would be compromised by an ugly emergency lighting luminaire. In this case a neat solution would be to use a unit, such as in Figure 7, and position it at floor level and direct the light towards the ceiling.

5.5. T-bay type or suspended fluorescent luminaires

These are suspended fluorescent luminaires specifically designed to replace hi-bay HID type fittings (T-bay types). As these luminaires are used at higher mounting heights it would be advisable to use a high emergency light output. (50 to 100%). It is also advisable to mount the batteries on the top surface of the luminaire. In this way, the battery service life will be extended significantly and battery access is simplified.

The battery placement suggestion applies to all suspended fluorescent luminaires because their cooler temperature may add another two years onto their service life.

5.6. Bulkhead luminaires

Very few bulkhead type luminaires are suitable for emergency lighting conversion because to temperature inside most bulkhead fittings, especially with high power lamps, rises to such high levels. It is a sad fact that, because our industry is ruthlessly driven by selling price, bulkhead fittings are mostly designed to be as small as possible and be able to house the largest possible wattage lamps thereby promoting the misconception that they offer the highest lumens per Rand.

By simply cramming more lamps into a fitting does little to improve lumen efficacy for two reasons:

- Higher lamp temperatures reduce lamp efficiency
- Radiation imprisonment and multiple internal reflections reduce lumen efficacy

It should be noted that the temperatures inside some bulkhead fittings are so high that they are not even suitable for use with electronic control gear (ECG) with their maximum temperature rating (t_a) of 70^0C! To make matters worse, many architects choose the slimmest designs (so they look unobtrusive), especially in stairwells. In most cases, a remote box should be used to house the batteries and control gear.

Figure 8

One neat solution is to use a double base or to use a combo type (see Figure 8) electronic ballast/control gear unit. Note that the wired bulkhead on the right is very crammed and that the electromagnetic ballasts are almost touching the batteries and emergency control unit. The gear on the left can provide the same performance with greatly improved reliability and enhanced lamp life. Wiring will also be reduced substantially.

5.7. Hi-bay fittings

Hi-bay type luminaires are used extensively above factory storage, production lines or in any areas where high ceiling and mounting height precludes the use of standard fluorescent fittings. The problem arises when emergency lighting is considered using these fittings because no cost effective emergency gear is available for use with HID lamps. Another problem with HID lamps is re-striking delay after a power failure of power dip. A number of solutions are locally available:

- Use 120 W PL lamps in a maintained, high emergency power configuration. In this way, the luminaire can provide full light output during normal conditions and sufficient emergency light to reach the distant floor below during a power failure.
- Use separate non-maintained 50 W halogen luminaires alongside the hi-bay luminaires. The directional, full brightness halogen lamps will provide sufficient emergency light to reach the floor below and they can be configured to provide light during the HID re-striking period.
- Provide an additional cut-out in the hi-bay for a PL lamp configured to provide non-maintained emergency lighting at high power.

Under no circumstances should the emergency gear be housed inside the hi-bay gear enclosure if an electromagnetic ballast is fitted due its high temperature rise. A common solution is to use double gear housings – one for the ballast and the other for the emergency gear.

Figure 9 shows a self-contained, non-maintained, self-testing emergency luminaire using a 50 W halogen lamp and featuring an infrared control unit interface to simplify testing and operation. This feature is especially useful when the unit is mounted very high.

Figure 9

5.8. Floodlight luminaires

There are no neat off-the-shelf solutions available to convert floodlight luminaires into emergency luminaires. In general, there is usually no space within the luminaire or ballast housing to fit any emergency gear and the temperatures inside the luminaire are usually too high for batteries. It is therefore prudent to position dedicated non-maintained emergency luminaires strategically around, for example a stadium car park, to provide lighting in the event of a power failure.

For this task, it is best to convert floodlights into emergency luminaires by removing the lamps and ballasts and fitting suitable lamps, control units and batteries. Examples of indoor, anti-panic area floodlights are shown in Figure 10.

Figure 10

5.8.1. Exit signs

Most exit signs in South Africa have emergency gear fitted as standard. These are mostly fitted with low wattage PL lamps and so heat rise is not usually an issue and space within the luminaire is sufficient for gear placement. However, a word of caution: The old European emergency lighting standard did not require battery cut-off for emergency gear using three or less cells. This was a major oversight because it means that the emergency light levels dwindle when the batteries become depleted until an effect called “arc to glow reversion” occurs which severely damages the lamp. This further complicates and increases maintenance costs.

6. Batteries

All reputable emergency lighting products use either nickel cadmium or lead acid rechargeable batteries. New legislation requires that correct charge and discharge criteria be met. It is also important to state the relative light output of the emergency luminaire (relative light output is the ratio of the emergency light output divided by the mains light output.). This information is thus essential when assessing products of dubious origin. This section provides simple calculations and measurements (using basic equipment) to ascertain the compliance of any emergency lighting luminaire. It describes the relationship between:

- Charging current and capacity
- Discharge current and capacity
- Discharge power and light output.

Charging current and capacity

A battery's capacity or energy storage ability is measured in ampere-hours (Ahr). This is the product of current and time. When charging a battery the rated capacity must be matched by the product of charge current and time. In other words:

$$C = I_c \times t \times 0.8$$

Where I_c is the charge current, t is the charge time in hours and *0.8* is the charging efficiency. New SABS legislation requires battery charging within 24 hours. If we wish to charge a 2 Ahr battery within 24 hours then the charge current must be:

$$I_c = \frac{2}{24 \times 0.8} \approx 100mA$$

The dangers in using a lower charging current are that the battery may not charge at all besides that fact that its charge current is illegal.

Discharge current and capacity

The value of the discharge current can, approximately, indicate the emergency lighting duration. This quite useful because standing and staring at an emergency light waiting to see how long it lasts is not fun. The relationship between discharge current, battery capacity and estimated emergency lighting duration is:

$$t = \frac{C}{I \times 1.2}$$

For example, if the battery capacity is 2 Ahr and the discharge current is 1 A then the expected emergency duration will be:

$$t = \frac{2}{1 \times 1.2} = 1.6 hours$$

The discharge factor increases with discharge current (especially with lead acid batteries) and battery capacity increases slightly after the first few discharge cycles.

Discharge power and light output

This approximation can only be obtained using fluorescent lamps. An interesting phenomenon occurs when driving fluorescent lamps at high frequency from an emergency lighting circuit. It so happens that increases in lamp efficiency swamp circuit losses enabling an almost direct comparison between battery consumption and lamp power. This allows a quick calculation of emergency light output by only using a multi-meter. The lamp power can be approximated by:

$$P = I \times V$$

Where *P* is emergency lamp power, *I* is the battery current and *V* is the battery voltage. For example, if an emergency pack uses a 12 V battery with a 36 W lamp and during emergency mode the current drawn from the battery is 2 A then the lamp power is:

$$P = 12 \times 2 = 24W$$

The relative light output will therefore be:

$$\frac{24}{36} = 67\%$$

Battery life

Any battery type begins ageing from the moment it is manufactured *i.e.*, it has a finite shelf and service life. In addition, every secondary (rechargeable) battery type can only be charged and discharged (cycled) a fixed number of times. This means that it is important to limit storage time before service and to limit the number of cycles during commissioning and testing.

6.1. Nickel cadmium batteries

Figure 11

Nickel cadmium (NiCad) batteries are by far the most popular battery for self-contained emergency lighting luminaires. The principle advantages of NiCad over other rechargeable types is lower weight for a given quantity of stored energy, good charging efficiency, small variation in terminal voltage during discharge, low internal resistance, and non-critical charging conditions – they can tolerate indefinite charging without damage. This simplifies the charging circuitry as no charge cut-off is required. Most emergency control units charge the batteries at a constant charge rate of C/20 (a current equal to a twentieth of the battery capacity).

Nickel-cadmium cells have a nominal cell potential of 1.2 V with an initial cell potential (immediately after charging) of 1.4 V and so a battery pack of 5 cells will initially provide 7 V after charging and then 6 V for most of the discharge period.

A low voltage cut-off is required in order to prevent reverse charging. Reverse charging occurs during discharge when a cell potential drops to zero and is then reverse biased by the other cells. Although this condition is reversible it usually requires a higher than normal charge current.

Nickel cadmium batteries may be stored with any state of charge for extended periods without any damage or reduction in service life.

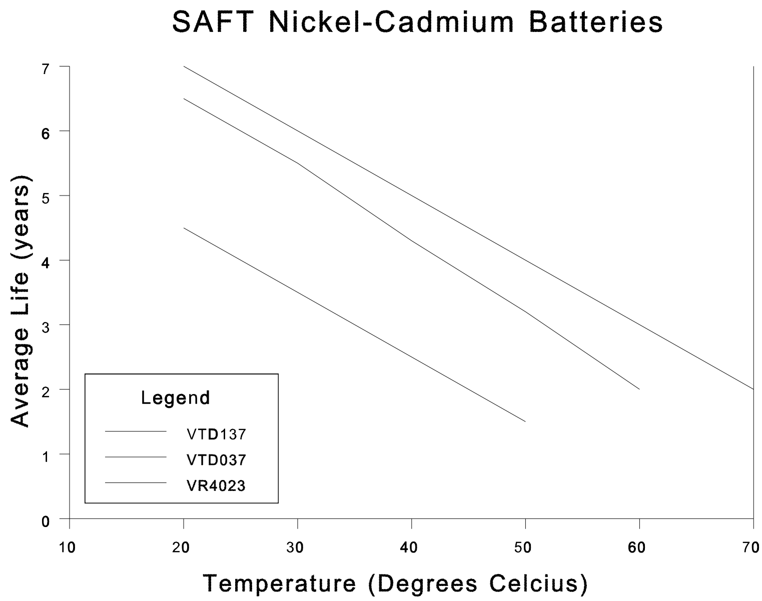


Figure 12

Figure 12 shows the predicted service life of various SAFT batteries versus ambient temperature. The graph shows that the life of all cell types is reduced by one year for every 10^{0}C rise in temperature. In order to achieve three years service life with high ambient temperature it is necessary to use only high temperature cells.

6.1.1. Handling safety/serious risks of injury

With a relatively low internal resistance, a NiCad battery can supply high surge currents. This characteristic can result in violent explosions if the battery leads are short circuited. There have been instances where exploding cells have torn through wooden doors! Even old, depleted batteries have destroyed rubbish bins after being discarded. Prevention of short circuits should therefore be treated as vital in order to prevent serious injury.

6.1.2. Disposal/environmental risk

Nickel cadmium batteries should not simply be discarded in the rubbish bin. Cadmium is used as an electrode material, the power source of the battery and is highly toxic to the environment. The amount of cadmium in Ni-Cads cannot be reduced because this would cause a proportionate reduction in the energy output of the battery. Cadmium typically accounts for 11 - 15 percent of Ni-Cad battery weight. The environmental release of cadmium poses potential health threats. Cadmium can accumulate in the environment by leaching into ground water and surface water from landfills, and it can enter the atmosphere through incinerator smokestack emissions. Cadmium is toxic to fish and wildlife and can pass to humans through the food chain. It has been associated with numerous human illnesses particularly lung and kidney damage. Once absorbed in the body, cadmium can remain for decades

6.1.3. Memory effects

It is claimed that NiCad batteries suffer from a so-called "memory effect" if they are recharged before they have been fully discharged. The apparent symptom is that the battery "remembers" the point in its charge cycle where recharging began and during subsequent use suffers a sudden drop in voltage at that point, as if the battery had been discharged. The capacity of the battery is not actually reduced substantially. Some electronics, designed to be powered by NiCad batteries, are able to withstand this reduced voltage long enough for the voltage to return to normal. However, emergency lighting products will be unable to get as much energy out of the battery, and for all practical purposes, the battery has a reduced capacity.

Memory effect can sometimes be reversed by putting the battery through several complete discharge and recharge cycles, which helps to recover the smaller crystal formations. This is called reconditioning. Many nickel-cadmium battery manufacturers either deny the effect exists or are silent on the matter.

If treated well, a NiCad battery can last for 1000 cycles or more before its capacity drops below half its original capacity

Nickel-cadmium batteries are readily available in either side-by-side or sausage configurations, the sausage configuration being preferred for slender luminaires.

6.2. Lead acid batteries

Sealed lead acid batteries provide the lowest specific cost (Rand/Ahr) of all batteries. They are maintenance free but cannot be stored in a discharged condition otherwise irreparable internal damage could result and the battery may no longer accept charge. It is therefore vital that any luminaire with lead acid batteries be put on charge as soon as possible after purchasing or after use. Furthermore, deep discharge is severely detrimental for any lead acid battery and the manufacturer’s minimum cut-off voltage requirements must be observed to prevent battery damage.

The charging requirements for lead acid batteries are also different to those of nickel cadmium and, under no circumstances, should battery types , even of the same voltage, be substituted. Whilst a nickel cadmium battery can tolerate continuous trickle charging a lead acid battery requires a very specific “float” charge. This voltage must be set very accurately in order to ensure battery longevity. The following are general voltage ranges for six-cell lead-acid batteries (12 V):

- Open-circuit (quiescent) at full charge: 12.6 - 12.8 V
- Open-circuit at full discharge: 11.8 - 12.0 V
- Low voltage cut-off: 10.5 V.
- Continuous-preservation (float) charging: 13.8V for gelled electrolyte

Note: All voltages are specified at an ambient temperature of 20^0C and must be adjusted for temperature changes. Float voltage recommendations vary, according to the manufacturers' recommendation. Precise (+/- 0.05V) float voltage is critical to longevity; too low is almost as bad as too high.

Never short the terminals of a lead-acid battery otherwise battery damage may result.

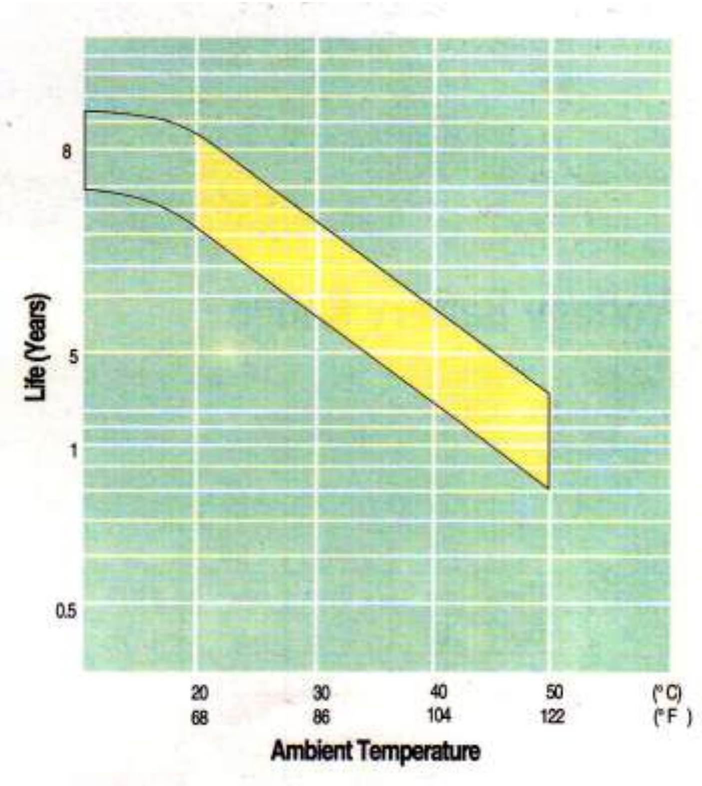


Figure 13

Figure 13 shows the effect of temperature on the service life of lead-acid batteries. It is clear that lead-acid batteries are much more sensitive to high operating temperatures than nickel-cadmium batteries. At an ambient temperature of 30^0C, the expected service life is about six years but at 50^0C the expected life drops to one year.

6.2.1. Disposal/environmental risk

Lead is one out of four metals that have the most damaging effects on human health. It can enter the human body through uptake of food (65%), water (20%) and air (15%). As far as we know, lead fulfils no essential function in the human body, it can merely do harm after uptake from food, air or water. Lead can cause several unwanted effects, such as:

- Disruption of the biosynthesis of haemoglobin and anaemia
- A rise in blood pressure
- Kidney damage
- Miscarriages and subtle abortions
- Disruption of nervous systems
- Brain damage
- Declined fertility of men through sperm damage
- Diminished learning abilities of children
- Behavioural disruptions of children, such as aggression, impulsive behaviour and hyperactivity

Lead can enter a foetus through the placenta of the mother. Because of this, it can cause serious damage to the nervous system and the brains of unborn children. Lead is a particularly dangerous chemical, as it can accumulate in individual organisms, but also in entire food chains.

6.3. Nickel metal hydride batteries

Nickel metal hydride (NiMH) batteries are the newest, and most similar, competitor to NiCad batteries. Compared to NiCad, NiMH batteries have a higher capacity and are less toxic, but are still slightly more expensive. In addition, a NiCad battery has a lower self-discharge rate (for example, 20% per month for a NiCad, versus 30% per month for a NiMH under identical conditions). A NiMH battery can have two to three times the capacity of an equivalent size NiCad and the memory effect is not as significant. As with NiCad batteries, their cell voltage is 1.2 V and permanent overcharging is permissible with currents up to C/10 h making them suitable for suitable for direct replacement of NiCad batteries in emergency lighting luminaires.

Care must also be taken during discharge to ensure that one or more cells in a series-connected battery pack, like the common arrangement of five C cells in series in a emergency luminaire battery pack, do not become completely discharged and go into polarity reversal. Cells are never absolutely identical, and inevitably one will be completely discharged before the others. When this happens, the "good" cells will start to "drive" the discharged cell in reverse, which can cause permanent damage to that cell.

Cadmium is poisonous, so NiMH batteries are less detrimental to the environment than NiCad batteries. Battery recycling programs exist to take care of end-of-life batteries. NiMH batteries are not altogether “green”, another issue is the environmental impact of nickel mines.

6.4. Proper disposal of batteries containing toxic materials

Both cadmium and lead are listed as hazardous chemicals and must be disposed of by our local environmental agency: Enviroserv. Their nation-wide branches will assist with the proper disposal in the following manner:

- Provide drums for the batteries
- Transport the drums to Holfontein land-fill site
- Cement encapsulate the drums for permanent underground storage to prevent the toxic chemicals from ever leaching into the soil

7. Measuring emergency light output

Measurement of emergency light output is required by legislation. It has to be specified as a percentage of the mains light output (or BLF). For multiple lamp luminaires with one lamp on emergency, this ratio must be the light output of the emergency lamp divided by the total light output of all the lamps in the luminaire. This process does not require any sophisticated photometric equipment, only a lux meter. This process will be explained on a channel type luminaire.

STEP 1:
Switch the lamps on using the mains supply.

STEP 2:
Place the lux meter directly on the emergency lamp and take a light reading (see Figure 14).

STEP 3:
Without moving the lux meter, switch over to emergency and take a light reading.

STEP 4:
The ratio of the two readings reveals the BLF.

Figure 14

8. Maintenance

Many international publications recommend daily checks on the emergency lighting, but this is ridiculous for a country that traditionally hardly ever checked its emergency lighting. It would be far more sensible to suggest checks in line with OHS Act mandatory checks of three-month intervals and to develop a test routine to satisfy local conditions. Now that it is mandatory to have the emergency system in good working order, it is important to ensure that any proposed system have the following attributes:

- An emergency lighting system that is easy to test
- An emergency lighting system that minimises damage to lamps and batteries
- Drawings of emergency luminaire locations in the building
- Readily available spares
- Easily replaceable batteries
- Wiring diagrams of luminaires (if in-house maintenance is used)

8.1. Three monthly tests

These tests should be conducted as quickly as possible not only to limit disruption to the workplace but also to limit damage to lamps and limit discharge from batteries. It should be preferably conducted at night so that easy identification of emergency function is possible. If conducted during the day the ambient light may make it difficult to see if some low power emergency luminaires are actually burning.

Self-contained emergency luminaires have both permanent and switched live feeds. A short-cut test scheme is to switch off the permanent live feed only thereby forcing the emergency lighting on whilst still maintaining normal lighting. This practice must be avoided especially with electronic ballasts because the excess voltages generated across the changeover device coupled with ballast open circuit conditions can lead to equipment damage or ballast shutdown. Only specially developed emergency gear will tolerate this test scheme. It is perhaps easier to test each lighting circuit separately in large or multi-floor systems.

These tests should be as conducted as follows:

- Locate emergency lighting drawing in order to identify where emergency luminaire are sited.
- Switch off mains power
- Check that all emergency luminaires and exit signs are functioning
- Restore mains power
- Log test date and details
- Conduct repairs if required

8.2. Annual tests

Annual tests must be conducted to ensure the lighting system meets its rated duration (emergency lighting time) and to discharge the batteries completely thereby removing any memory effect (nickel-cadmium batteries). Again, this test should be conducted at night to enable easy identification of emergency luminaires and for least disruption of the workplace. This test should proceed as follows:

- Locate emergency lighting drawing in order to identify where emergency luminaire are sited.
- Switch off mains power
- Check that all emergency luminaires and exit signs are functioning
- Wait for the rated duration to elapse (one or three hours)
- Check that all emergency luminaires and exit signs are functioning
- Restore mains power
- Log test date and details
- Conduct repairs if required

A proposed test schedule is given below. An attempt has been made to include as little data as possible because experience has shown that if too much input is required then the whole process may be neglected:

Building name (QUICK SPAR – Pofader)				
Circuit name (Butchery circuit)				
Date	**Test duration**	**Results**	**Actions**	**Signature**
6/07	5 min	Exit sign #1 not working	Replaced PL9W lamp- all OK	

9. Common faults and problem areas

This section identifies common design problems and maintenance issues in order to assist with the selection of an emergency lighting system and to guide maintenance personnel. The most important starting point in selecting any emergency lighting system is to first identify a reputable lighting company because emergency lighting is a specialised and highly technical field that requires specialist knowledge to reduce system cost, meet legislation and reduce maintenance costs. It is a sad fact that South African is awash with emergency lighting systems that do not function, that many systems cannot be repaired without complete renewal and that maintenance was and still is seldom considered.

9.1. Excessive temperatures

In South Africa, heat is the most damaging effect on emergency lighting. Heat ages the emergency control unit, wiring, connectors, plastics and batteries and, as Chapter 6) revealed, all batteries are very sensitive to elevated temperatures. There are many instances where batteries are installed in such hot luminaires that their expect life will only be a few weeks! Current legislation tacitly implies that the battery temperature should not exceed 50^0C but there are moves afoot to legislate specific limits on battery temperature.

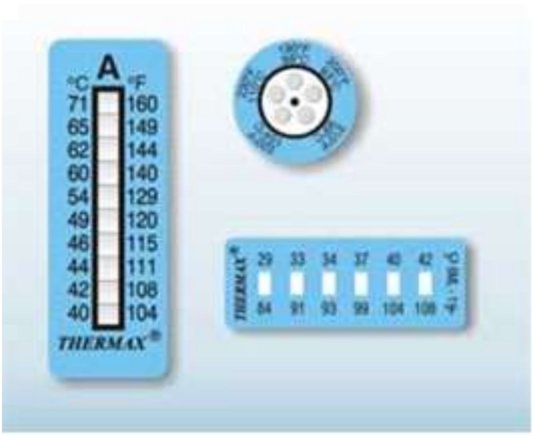


Figure 15

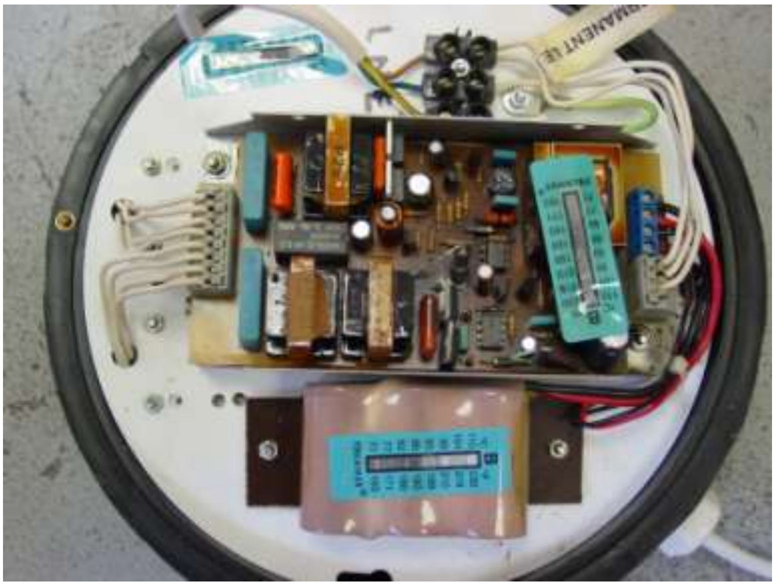


Figure 16

Figure 17

9.1.1. Corrective action

It there is any doubt, temperature tags (see Figure 15) should be used to establish heat rise inside the luminaire with all lamps burning. These tags discolour when they exposed to high temperature and record the highest temperatures attained. They are particularly useful in areas where it is not possible to use a temperature probe. The luminaire should be left burning for about an hour to allow the temperature to stabilise. After the test, the tags (see Figure 16) will indicate the temperature rise at critical (batteries) points inside the luminaire. Note that the temperature inside the combo ballast exceeded 100^0C! In this case (2 x PL26 W) the battery temperature exceeded 88^0C (see Figure 17) and only provided a service life of three months. It is important to also measure the ambient temperature outside the luminaire to compute the heat rise (Δt) where:

$$\Delta t = t_c - t_a$$

Where t_c is the temperature of the component and t_a is the ambient temperature. Suppose the temperature tab measured a temperature of 70^0C and the ambient temperature was 25^0C then the temperature rise (Δt) would be:

$$70 - 25 = 45^0\text{C}$$

It is now possible to predict the temperature of that particular component at any ambient temperature. For example, on a hot summer's day in Johannesburg the ambient temperature may rise to 40^0C. The temperature of the batteries would therefore rise to:

$$40 + 45 = 85^0\text{C!}$$

Clearly this temperature will cause rapid battery and control unit ageing. The solution to this particular problem would be to house the battery and control unit in a separate housing or use a cooler luminaire.

Figure 18 shows the temperature rise inside a typical bulkhead fitting with 2 X PL9 W lamps and a deep prismatic lens using both plastic and aluminium bases. It is interesting to note that the aluminium base (lower curve) dissipates heat better than the plastic base by about 5^0C.

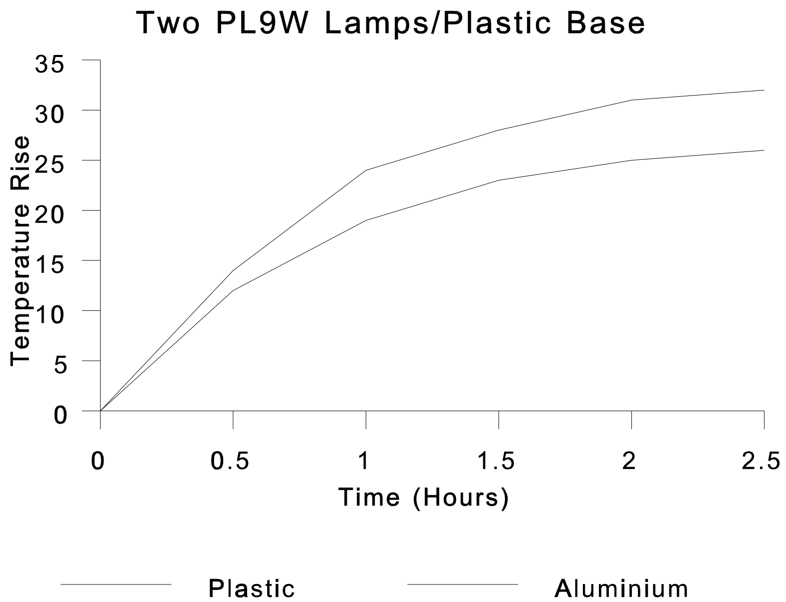


Figure 18

Figure 19 shows the temperature inside the back of the bulkhead (where the emergency gear would be fitted) with different luminaire orientations (upper trace = horizontal, lower trace = vertical) with same fitting as used in the above experiment. This graph serves to indicate how important it is to be aware of how different conditions will markedly affect battery life.

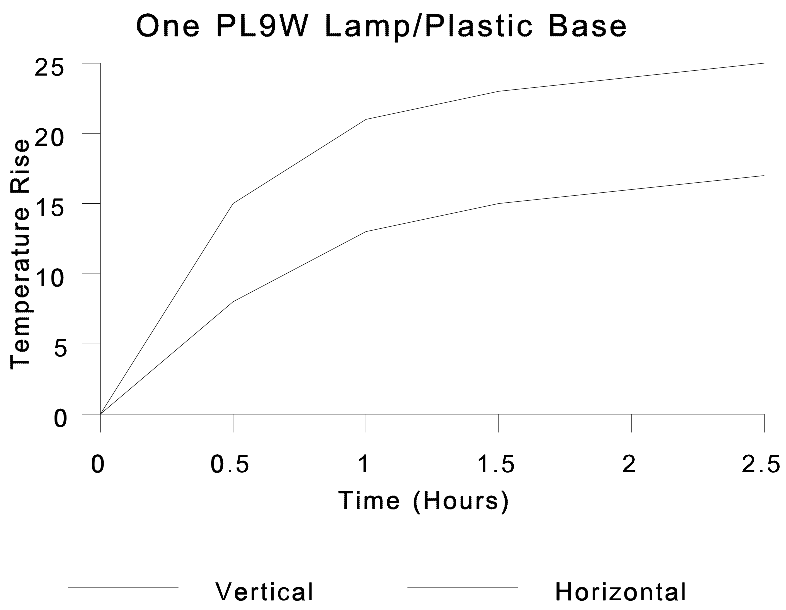


Figure 19

9.2. Lamp damage

Figure 20

Lamp damage is usually limited to fluorescent lamps used in emergency mode. It is characterised by tube end blackening (see Figure 20), which indicates damage to the electrodes, and affects all currently available products (because they do not use external cathode heating). This effect can be exacerbated by:

- Bad control unit design that does not ensure an arc discharge
- Operation in non-maintained mode
- Excessive emergency cycles

Poor control unit design may cause the lamp to run in a glow discharge mode. This mode is characterised by a bluish glow at either end of the lamp and is highly damaging to the lamp. In some cases, it may cause complete lamp failure within one minute! Another problem to plague marginal designs is arc to glow reversion as the battery runs flat, which has the same damaging consequences, but will only occur towards the end of the emergency lighting cycle. To overcome this phenomenon it is best to purchase products with a good record of success from establish lighting suppliers.

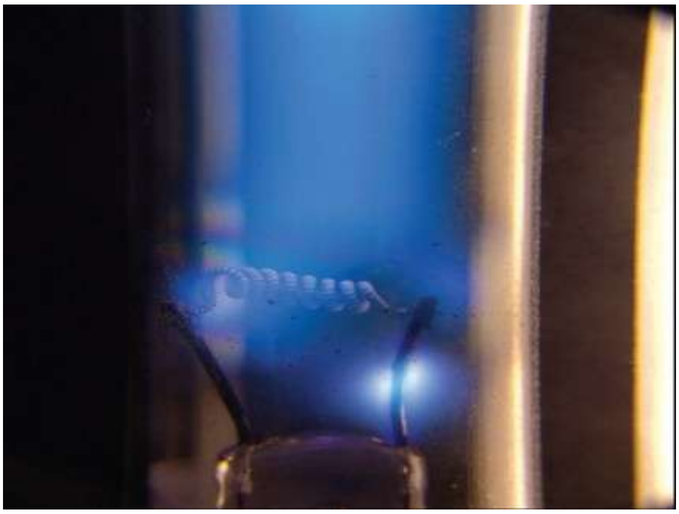


Figure 21

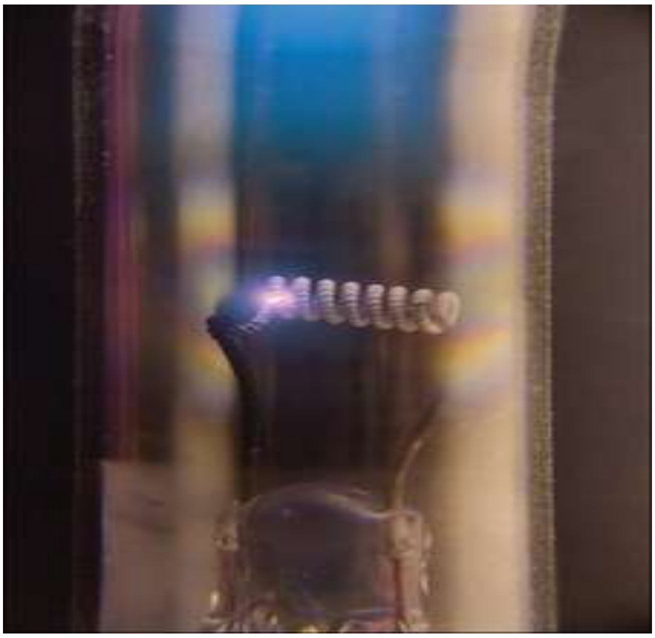


Figure 22

Figure 21 and Figure 22 show a close up photograph of an electrode of a germicidal lamp operating in both glow and arc discharge modes. The glow discharge mode (Figure 21) is characterised by a bluish glow on the electrode (this is also visible on normal fluorescent lamps) that causes considerable damage to the electrode. This glow discharge operation may occur briefly as the lamp first switches on but the blue glow should extinguish within seconds to preserve the electrodes. These observations may be necessary in determining why certain lamps suffer premature damage in an emergency lighting installation.

Whenever testing any emergency lighting system using fluorescent lamps it is best to select maintained mode (if possible) because the lamp starting in emergency mode will not cause any lamp damage.

Excessive emergency cycles will damage all fluorescent lamps (and batteries) and so it is best to ensure that batteries in self-contained emergency luminaires are left disconnected during building construction.

A damaged emergency lamp may well work in emergency mode but may not function during normal mode (maintained operation) because emergency operation does not require intact filaments.

9.2.1. Corrective action

Ensure that the luminaire is not in emergency mode when changing the lamp because unnecessary lamp damage will result during insertion. If the luminaire is connected in maintained mode then also ensure that the luminaire is not switched on otherwise ballast shutdown (if electronic ballasts are fitted) may occur.

9.3. Battery damage/end of life

All emergency lighting systems have a charge indicator light. For nickel-cadmium batteries, this light indicates that the batteries are being trickle charged. For lead-acid batteries the charge indicator light shows that the batteries are being boost charged – at the end of boost charge the light goes out and there is no way of determining if the battery is charged other than by initiating an emergency light cycle. If the emergency luminaire does not function in emergency mode, it could be due to a number of battery issues:

9.3.1. Old age

The symptoms are that the luminaire does not provide the rated duration after a charge cycle in excess of 24 hours. Check the commissioning date stamped on the battery pack. Usually if the battery is three years or older it needs to be replaced. Replace it with the same type as indicated on the label.

9.3.2. Battery open circuit

This fault often occurs with nickel-cadmium battery packs if the pack is dropped or man handled causing a break in the interconnections between cells. The battery pack must then be returned to the manufacturer for repair or replaced.

An open circuit lead-acid battery will not accept a charge. The problem may be caused by storing the battery in an uncharged state. This problem may sometimes correct itself by connecting the battery to a charging circuit only after a significant time. Usually the battery never accepts charge again and requires replacement.

9.3.3. Excessive cycling

If the battery is relatively new, does not operate at excessive temperatures but still does not provide the rated lighting duration then the problem could be that the battery pack has endured excessive cycles. This is usually due the following problems:

Excessive cycling during installation
The batteries were supplied connected in the emergency luminaire and during building wiring and testing the emergency light suffered numerous charge and discharge cycles. The solution to this problem is to supply the luminaire with the battery disconnected and to connect the batteries before building commissioning.

Permanent live and switched live wires are joined together.
This is a common problem where the electrician connects the emergency luminaire the same as normal lighting from a switched live supply (and no separate permanent mains connection). The result is that the batteries get charged when the lights are switched on in the morning and are then depleted when the lights are switched off at night. A related complaint is that the emergency lighting duration is way below the rated value during commissioning.

9.3.4. Battery disconnected

This simple problem is a source of much mirth but it continues to be a reason why the emergency lighting does not work.

9.3.5. Battery replacement

This requirement is sometimes overlooked during luminaire manufacture and can cause maintenance trauma because in many cases it is not easy to replace the batteries. In most cases, nuts and bolts are used. During manufacture, it may be easy to access both sides (inside and outside) of the luminaire but with installed recessed luminaires, this may be a problem.

STEP 1
The first step is to disconnect all mains power from the fitting before setting to work.

STEP 2
Disconnect the old battery and insulate its terminals so that they cannot be shorted.

STEP 3
Remove the old battery pack. This may not be an easy task especially if nuts and bolts were used because it may be difficult to access the other side of the fitting to hold the bolt.

STEP 4
Install the new battery pack and inscribe the installation date.

STEP 5
Connect the battery terminals to the control unit. Beware of the polarity!

STEP 6
Reapply power and observe that the battery charge indicator is lit.

9.4. Wiring problems

Wiring between the emergency gear/lamp/ballast should be kept as short as possible to reduce electromagnetic radiation (radio interference) and to ensure that the emergency.

A common fault on two lamp channel fittings is the lamp holders at one end are swapped in assembly. The result is that the lamps may work (electromagnetic ballast) on mains but fail to work in emergency mode.

9.5. Labelling

Figure 23

Every emergency luminaire must be labelled (see Figure 23). The label describes the type of emergency luminaire, its operational mode and the emergency lighting duration. Labelling continues to be an issue in South Africa despite mandatory requirements. There are two reasons for this. The first is perhaps the very stringent requirements for indelible marking that makes logistics difficult with the vast array of luminaire types. The other reason is aesthetics – conspicuous labels on emergency fittings do not sit comfortably with attractive décor. This results in it being difficult to easily identify emergency fittings an further complicates testing. It is very important that the emergency luminaires are easy to identify and indicator lamps being visible without (in conflict with regulations) having to remove diffusers.

9.6. Indicator lamp placement

The indicator lamp must be visible from floor level so that maintenance personnel can establish if the batteries are being charged. This requirement usually poses problems with recessed type fittings because the indicating lamp is often tucked behind the diffuser or the luminaire lamps swamp its meagre light output.

In view of the legal requirements to regularly test emergency lighting and keep it in good working order, it is essential that emergency luminaires are easily identified from floor level and their operational status is easily ascertained amongst a myriad of similar looking luminaires.

10. Design considerations

10.1. Design Objective

When the supply to any part of the normal lighting fails, the requirements of SABS 0114-2 apply and escape lighting is required to fulfil the following functions:

- Show clearly and unambiguously the escape routes. This calls for the use of exit signs. These should comply with SANS 1186-1/3. Exit signs should be visible from any point on the escape route.

- Provide illumination along the escape routes to allow safe movement towards and through the exits by luminaires spaced at appropriate intervals.

- Ensure that fire alarm call points and fire fighting equipment provided along escape routes can be readily located.

- Permit operations concerned with safety measures to continue.

10.2. Initial information required

Before designing an emergency lighting scheme, the following information needs to be determined from the site drawings or from the specifier:

- The duration of the emergency lighting required. Three-hour duration is required in places of entertainment and for sleeping risk. Three hour duration is required if evacuation is not immediate, or early re-occupation is likely to occur. One-hour duration may be acceptable in most cases if evacuation is immediate and re-occupation is delayed until the system has recharged.

- Emergency lighting should be of the maintained type in areas in which the normal lighting can be dimmed.

- The draft standard SANS 0014-2 requires that exit signs are of the maintained type where the premises are used by people who are unfamiliar with its layout.

- Building plans need to be assembled showing the location of the fire alarm call point positions, the positions of fire fighting equipment, and fire and safety signs.

- Emergency escape routes should be established, and potential hazards investigated.

- Open areas larger than 60m^2 floor area should be identified.

- High-risk task areas should be identified and normal lighting levels established.

- The need for external illumination outside final exit doors and on a route to a place of safety should be determined.

- Other areas that need illumination, although not part of the escape route, should be located, e.g. lifts, moving stairways and walkways, plant rooms and toilet accommodation over 8m^2 gross area.

- If a central system is being used, the locations of central battery units and cable runs should be established in areas of low fire risk.

- Individual lighting circuits need to be identified so that failure of any circuit activates its own emergency lighting.

- Standby lighting requirements should be used if activities need to continue during a failure of the normal lighting supply.

- The customer's preference and operating considerations should be ascertained, e.g. ceiling heights, mounting heights or wall mounting.

- Most importantly: budget. It is pointless to design any system without a budget in mind. Invariably the client will want to spend the minimum amount of money on the emergency lighting and it is the designer's duty to inform the developer of the dangers involved in not considering maintenance and support issues.

10.3. Location of luminaires at points of emphasis

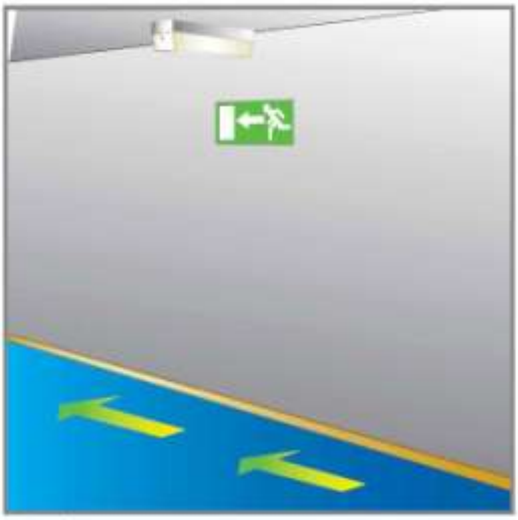
The first part of the design procedure is to determine the siting and positions of luminaires to account for specific hazards and to highlight all safety equipment and directional signs. This is to be performed regardless of whether the luminaires are sited on an emergency escape route or in an open anti-panic area. Certain points are more important and referred as "points of emphasis". These points of emphasis should be illuminated by a luminaire and directional sign (exit sign):

- At each door that is intended to be used in an emergency
- To illuminate exit and safety signs
- Near each staircase so that every flight of stairs receives direct light

- Near any other change in floor level
- Near each change of direction
- Near the intersection of corridors
- Near every fire alarm call point
- Near every unit of fire fighting equipment
- Outside each final exit and close to it
- Near first aid points

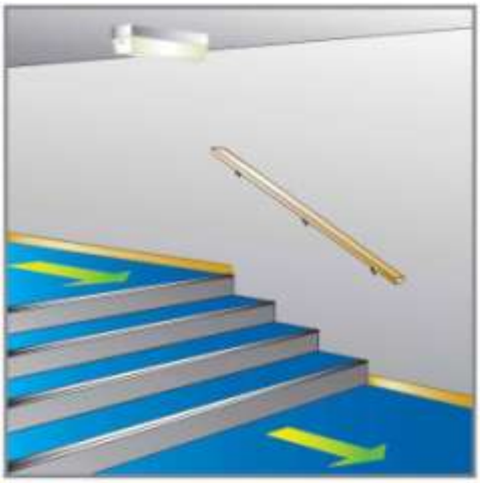
“Near” is described as being within 2m measured in a horizontal direction. We can overview escape routes and exits as those being the most direct, unambiguous and practical ways to the final exit points out of the building. The required illuminance at safety equipment and near points of danger is a minimum illuminance of 5 lux out to a horizontal distance of 2 m.

At each exit door



All safety exit signs

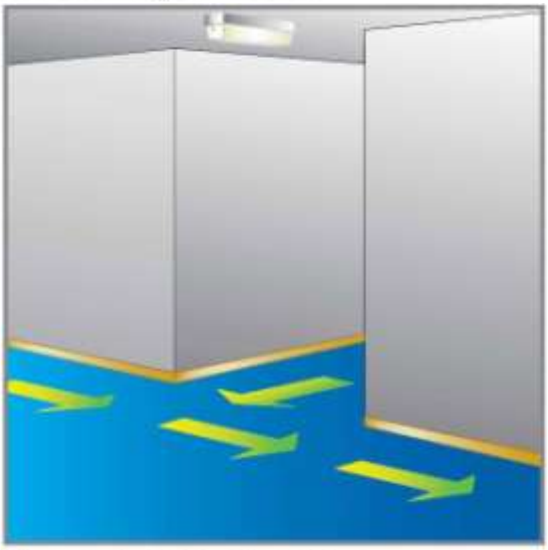
Outside and near each final exit



Near stairs so that each tread receives direct light

At each change of direction

Near each first aid post

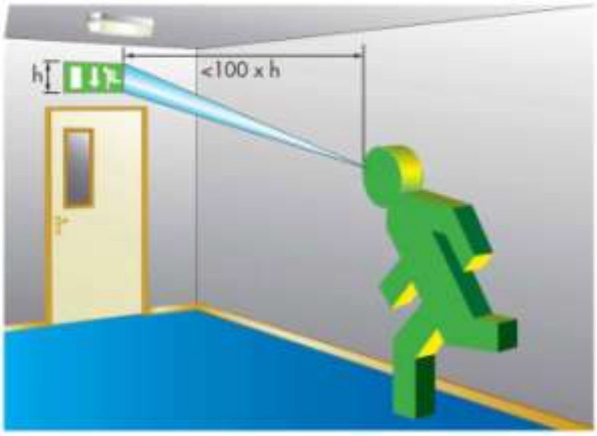


At each intersection of corridors

Near each piece of fire fighting equipment and call point

10.4. Positioning and size of exit signs

Exit signs must be installed at all final exits and on escape routes at any location where the route may be in doubt. Where direct sight of an exit or emergency exit is not possible and in doubt, a directional sign or series of directional signs should be provided so that a person moving towards it will be progressed towards and exit. Therefore, the exit and direction signs must be visible from all points on an escape route.



Exit signs are to be wall mounted at a height of 2 to 2.5m above floor level. This is the height at which a human is accustomed to look for a sign.

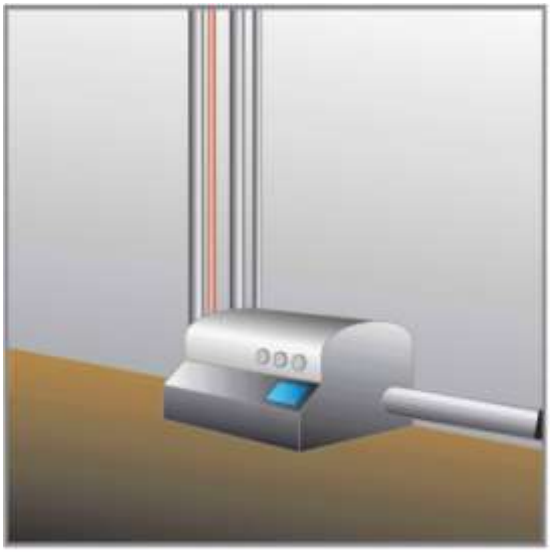
It is to be noted that if the normal lighting is dimmed *i.e*., in lecture theatres and cinemas, the exit sign must be maintained at full brightness.

The maximum viewing distance is given by 200 x the exit panel height. Therefore, if the logo height is 120mm then the maximum viewing distance is 24 m. The viewing distance is reduced to 100 x sign height for externally illuminated signs.

10.5. Additional emergency lighting

Although not part of the escape route, certain other additional areas require the use of emergency lighting because they are classed as risk areas. These locations are:

- Lift cars. Although they may be part of the escape route in exceptional circumstances, they may present a problem if the public are trapped in them in the event of a supply failure.
- Toilet facilities and other open tiled areas exceeding $8m^2$ floor area and all toilets for the disabled.
- Escalators, to enable users to get off them safely.
- Motor generator, control or plant rooms require battery supplied emergency lighting to help any maintenance or operating personnel.
- Covered car parks along the normal pedestrian routes



10.6. Illuminance requirements for escape routes

In addition to luminaires at the points of emphasis, it may be necessary to provide extra luminaires to ensure that minimum light (illuminance) levels are met along the whole escape route. Here the requirement is 0.3 lux minimum along the centre line of the escape route with a maximum uniformity ratio of 40:1.

10.7. Photometric design

An important aspect to any emergency lighting installation is the photometric performance. This section provides a brief overview for first iteration lighting design if comprehensive tools, such as Relux™, are not available to the user.

Fluorescent lamps are generally used to provide emergency lighting in escape routes (minimum of 0.3 lux) and anti-panic areas (minimum of 0.5 lux).

10.7.1. Spacing tables (linear fluorescent)

Spacing tables provide the information to help you decide whether additional fittings are needed besides those required for the points of emphasis. SABS registered luminaires have been independently tested to photometric performance and the tables generated have been third party inspected.

	Escape routes 1 lux minimum along centre line				Open (anti-panic) areas 0.5 lux minimum Luminaires arranged in a regular array			
Ceiling mounting height (m)	Transverse to wall	Transverse spacing	Axial to wall	Axial spacing	Transverse to wall	Transverse spacing	Axial to wall	Axial spacing
2.5	1.8	5.6	1.5	4.7	2.1	5.6	1.7	4.6
3	1.5	5.5	1.2	4.6	2.0	5.8	1.7	4.8
4	-	-	-	-	1.7	5.8	1.5	4.9
5	-	-	-	-	0.8	5.4	0.6	4.6

10.7.2. Rough lighting calculations (linear fluorescent)

In contrast to designs using halogen lamps, only average illuminance values can be readily computed. Also, it must be borne in mind that point illuminance calculations are dependant upon many factors including luminaire type.

Example

A shopping department floor 30 m long and 25 m wide requires open area anti-panic emergency lighting. Maintained emergency lighting must be provided using 1 x 36 W channel type luminaires. Calculate the number of emergency lamps required with an output of 15%.

The formula for average horizontal illuminance is given by:

$$E_{av} = \frac{\phi_{tot} \times \eta_{wp} \times M}{A} \quad [1]$$

Where E_{av} is average horizontal illuminance at ground level, Φ_{tot} is the total luminous flux of the lamps, η_{wp} is the utilisation factor for the working plane, M is the maintenance factor and A is the surface area.

We require an average horizontal illuminance (E_{av}) of 0.5 lux.

The total floor area (A) is 30 x 25 = 750 m^2.

The *Maintenance Factor* (M) is the ratio of the light output of an old lamp to the light output of a new lamp. We will assume that the lamps will be replaced when their light output has dropped to 80%. Therefore M = 0.8.

The *Utilisation Factor* (η_{wp}) is the ratio of usable light flux to total light flux. (Not all the light emitted from the lamp actually arrives at the working surface. Some light may be absorbed by the walls and ceiling with channel type luminaires. With recessed luminaires, some light will be trapped inside the fitting or absorbed by other lamps.) We will assume a poor case scenario where half the light emitted from the lamp is absorbed or lost *i.e.* $\eta_{wp} = 0.5$.

From equation [1] the total flux required is approximately 1000 lm.

The output of a standard 36W fluorescent lamp is 2600 lm. In emergency lighting mode, the lamp output will only be 15%, or 390 lm.

It follows that, using the above simplistic assumptions; only three lamps are required on emergency to provide an average illuminance of 0.5 lux.

10.7.3. Rough lighting calculations (halogen)

Halogen spot lights may be used to provide emergency lighting for high-risk task areas (minimum of 20 lux) or where high mounting heights preclude the use of fluorescent lamps for escape route lighting (minimum of 0.3 lux). The lamp beam angle will be chosen to suit the application. In general, low beam angles for high-risk task area lighting and wide beam angles for escape route lighting where wide luminaire spacing is desired (to reduce costs).

Example
An escape route requires emergency lighting with a mounting height of 20 m. Calculate the optimum halogen lamp and spacing.

Note: All Cosine emergency lighting products provide 100% light output on emergency with halogen lamps. It is therefore possible to use lamp manufacturer's data without correction.

The formula for point illuminance calculations is:

$$E = \frac{I \cos^3 \alpha}{h^2} \quad [1]$$

Where E is illuminance at ground level, *I* is the luminous intensity of the light source, *h* is the mounting height and *α* is the angle between the normal and the measured point.

If we use 50W lamp with a 36^O beam angle (half intensity at 36^O = 1600/2 = 800 cd) then the minimum illuminance (lux at 36^O at floor level) will be:

$$800 \times \cos^3(36) / 20^2 = 1 \text{ lux}$$

The spacing between luminaires (*S*) is given by:

$$S = 2h \times \tan \alpha \quad [2]$$

As the mounting height is 20 m and α is 36^O, it follows that the spacing between the luminaires can be 30 m.

The uniformity ratio is defined as:

maximum illuminance / minimum illuminance [3]

The maximum allowable uniformity ratio for escape routes is 40:1.

The minimum illuminance was already calculated to be 1 lux.

The maximum illuminance will be directly under the luminaire and is given by:

$$E = \frac{I}{h^2} \quad [4]$$

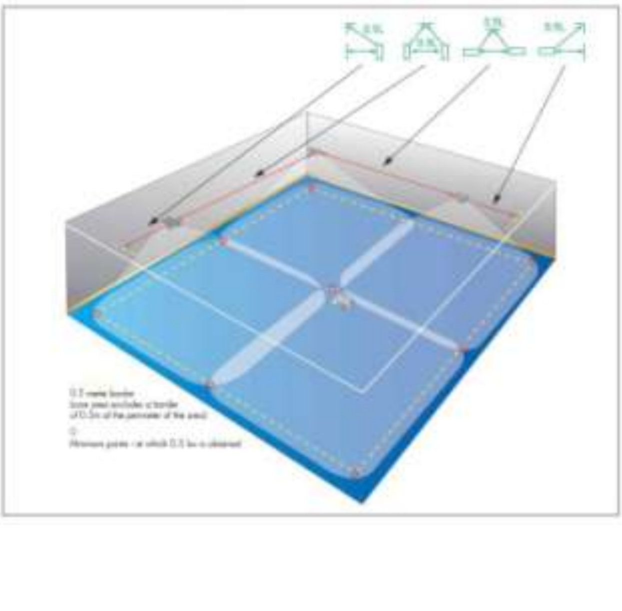
Using I = 1600 cd and h = 20 m. Then E = 4 lux.

The uniformity ratio will therefore be 4:1, which is acceptable.

Notes
In the above example, the minimum illuminance from a single luminaire is calculated to be 1 lux. However, the total contribution of adjacent luminaires will be double this figure, *i.e.*, 2 lux. It would therefore be possible to use a 20 W 36^{O} lamp that has a third of the intensity of the 50 W version.

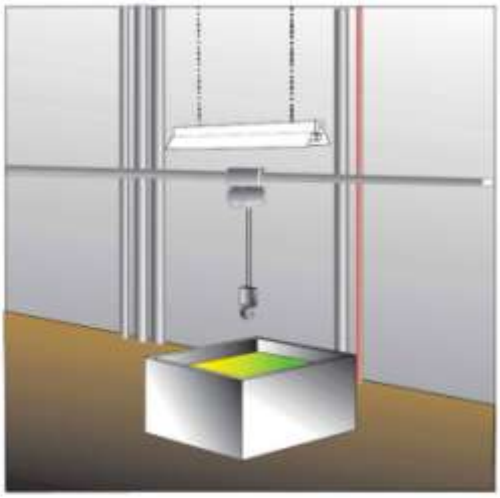
10.8. Illuminance levels for open areas

Emergency lighting is required for areas larger than 60m^2 or open areas with an escape route passing through. The general requirements are an Illuminance of at least 0.5 lux at empty floor area up to a height of 0.5 m on the perimeter with a maximum uniformity ratio of 40:1



10.9. High-risk task area lighting

This sector of emergency lighting safeguards occupants involved in a potentially dangerous process or situation and allows the correct shutdown procedures to be implemented. This is for the safety of both the operators and others using the building. Included in these areas are high physical risk environments of dangerous plant and production lines such as lathes and conveyor belts.



The general requirements are an Illumination of at least 10% of normal lighting or 20 lux, whichever is greater with a maximum uniformity ratio of 10:1 within 5m of task.

To design for these areas small fluorescent lamps are not always satisfactory and it may be necessary to use large, higher-powered fluorescent lamps running at high light outputs or halogen spot lamps. To avoid undue glare these should be mounted at least 30^0 above the line of sight.

10.10. System selection

10.10.1. Self-contained emergency luminaires and signs

Are the luminaires positioned along the escape routes at the correct spacing to ensure that the required illuminance levels are achieved? The SABS mark is the best means of assuring that the luminaires meet the photometric performance claims.

Are the luminaires positioned in open areas (anti-panic areas) at the correct spacing to ensure that the minimum illuminance level is achieved?

Are the non-maintained luminaires fed from the same final circuits as the local lighting?

Are there at least two luminaires in each “lighting compartment” to ensure that the area is not plunged into darkness if a luminaire fails?

Are additional luminaires provided in lift cars, escalators, toilets, etc?

Are hazardous areas illuminated at 10% of normal illuminance?

10.10.2. Central battery systems

Will the emergency lighting be activated on the failure of any circuit covered?

Does the central battery system comply with SABS 1464-22?

Is the battery charger functioning?

Where applicable, are the battery electrolyte levels and specific gravities satisfactory?

10.11. Testing and log book

The system should include adequate facilities for testing and recording the system condition. These need to be appropriate for the specific site. It might be feasible to test the installation in an office block by isolating the total supply. This would be inappropriate, however, in a hotel occupied 24 hours a day. A test system able to operate alternate fittings would be more suitable to eliminate the risk of having all the luminaires discharged while the building is occupied.

A logbook should be kept readily available for inspection. It should record the date and brief details of completion, any alterations, periodic inspections and test certificates, each service, inspection or test carried out, defects and remedial action.

10.12. Maintenance aspects

Essential servicing should be defined to ensure that the system remains at full operational status. This would normally be performed as part of the testing routine, but for consumable items, such as replacement lamps, spares should be provided for immediate use.

11. Generator Sets

Generator sets are becoming popular in South Africa due to our unreliable mains supply. They range from small portable units of 2 kW to large automatic changeover systems of 50 kW or more.

The huge advantage of a motor generator set over UPS Systems is cost and the fact that the voltage waveform from a motor generator set is sinusoidal. They are therefore suitable to drive any appliance that is normally powered from mains. Generally, their load regulation is poorer than UPS systems because of the reliance on a mechanical throttle mechanism. Small capacity units can suffer alarming power dips and surges during load switching. This negative aspect must be borne in mind when powering sensitive electronic equipment such as computers. Other negative aspects include:

- noise,
- start-up time,
- generation of toxic gases and
- reliance on single power source (no redundancy).

The problems of start-up time and redundancy necessitate the use of self-contained emergency luminaires to complement the generator set. All too often, there are problems starting the generator or the generator circuit breaker trips due to overloading. It is therefore imperative that self-contained emergency lighting is also provided for anti-panic and escape purposes and that a luminaire is positioned above the generator (see high-risk task area lighting).

The problems of noise and exhaust gases will have an important impact on generator positioning and installation. The exhaust gases should be directed up and away from personnel because a lengthy power failure of, say, two hours will produce considerable fumes that permeate through open windows and doors to create unpleasant odours besides the health risks.

11.1. Selecting an appropriate generator

The table below indicates starting and running power of many appliances. It is vital that the selected generator be able to provide power during start-up otherwise the generator's circuit breaker may trip or large voltage dips may occur.

Typical Electrical Appliance Wattage's		
Application / Equipment	Running/Rated Watts	Starting/Surge Watts
Light Bulb (100w)	100	100
Radio AM/FM	50-200	50-200
Radio, CB	50	50
Fan	200	600
Television	300-400	300-400
Microwave Oven	700	1000
Air Conditioner (12,000 BTU)	3250	5000
Furnace Fan (1/3 hp blower motor)	600	1800
Vacuum cleaner	600	750
Sump pump (1/3 hp)	700	2100
Refrigerator/freezer	800	2400
Deep Freezer	500	1500
Circular saw	1000-2500	2300-4600
Circular saw 6"	800	1000
Floodlight	1000	1000
Drill 1/2" Electric	1000	1250
Toaster	1200	1200
Coffee maker	1200	1200
Skillet	1200	1200
Chain saw 14" Electric	1200	1500
Water well pump (1/2 hp)	1000	3000
Hot plate/range (per burner)	1500	1500
Table saw 10"	2000	6000
Water heater (storage type)	5000	5000
12V DC Battery Charger	120	120

Both the generator and the engine powering the generator are often sold together as a single package or "genset."

11.1.1. Manual generators

These are typically of lower capacity, are petrol driven and have no changeover facility. They are available in both pull start and electric start versions. **Note: Manual/temporary generators must be used with caution due to changeover considerations and safety (Chapter 13)**.

11.1.2. Automatic generators

These are typically larger capacity diesel driven units with automatic start and changeover facilities.

11.2. Safety Practices

- Treat all installation as live even during a power outage.
- Never run a generator in an enclosed area.
- Keep all guards and shields in place to protect the operator from moving parts.
- Always check for downed power lines or damaged circuits before connecting a generator.
- Use extreme caution, especially under wet conditions.
- Never refill (fuel) a generator engine that is hot or running.
- Never shut off the generator under load.
- Never store gasoline indoors or near the generator where gas vapours could be ignited by a spark from the generator.

11.3. Generator Maintenance

Service for the generator set is much like the service you perform on your automobile. The generator set should have oil and all filters changed at least once a year. Fan belts should be checked for cracks and replaced every couple of years to prevent over-heating. The radiator anti- freeze should be drained periodically and replaced to prevent deterioration. The generator should be kept free from dust and occasionally connections should be checked for looseness. These procedures are normally done every so many hours of engine operation i.e., 100 to 200, depending on manufactures suggested maintenance schedules. Severe weather patterns can increase the maintenance requirements, i.e., excessive dust, heat, moisture. The unit should also be checked from an electrical standpoint to be sure that it is performing as it was designed.

12. UPS Systems

An Uninterruptible Power Supply (UPS), also known as an Uninterruptible Power Source, Uninterruptible Power System, Continuous Power Supply (CPS) or a battery backup is a device that maintains a continuous supply of electric power to connected equipment by supplying power from a separate source when utility power is not available.

There are two distinct types of UPS: off-line and line-interactive (also called on-line). An off-line UPS remains idle until a power failure occurs, and then switches from utility power to its own power source, almost instantaneously. An on-line UPS continuously powers the protected load from its reserves (usually lead-acid batteries or stored kinetic energy), while simultaneously replenishing the reserves from the AC power.

The on-line type of UPS, in addition to providing protection against complete failure of the utility supply, provides protection against all common power problems, and for this reason it is also known as a power conditioner and a line conditioner.

While not limited to safeguarding any particular type of equipment, a UPS is typically used to protect computers, telecommunication equipment or other electrical equipment where an unexpected power disruption could cause injuries, fatalities, serious business disruption or data loss. The UPS power is sometimes also used to provide standby and/or emergency escape lighting. The lighting is operated in this mode at 100% brightness and so the emergency load must be computed with this in mind. Also, other SABS requirements such as distributed escape route lighting, initiation after the failure of each lighting circuit and a preference for distributed power sources must be accommodated.

UPS units come in sizes ranging from units which will back up a single computer without monitor (around 200 VA) to units which will power entire data centres or buildings (several megawatts). Larger UPS units typically work in conjunction with generators.

Historically, UPS’s were expensive and were most likely to be used on expensive computer systems and in areas where the power supply is interrupted frequently. As prices have fallen, UPS units have become an essential piece of equipment for data centres and business computers, and are also used for personal computers, entertainment systems and lighting. In South Africa, where the electrical grid is under strain, providers struggle to ensure supply during peak demand (such as summer, when air-conditioning usage increases). To prevent unplanned blackouts, ESKOM use a process called load shedding, which involves cutting the power to large groups of customers for short periods of time.

A UPS should not be confused with a standby generator, which does not provide protection from a momentary power interruption and may result in an interruption when it is switched into service, whether manually or automatically. Such generators are typically placed upstream of the UPS to provide cover for lengthy outages. Integrated systems that have UPS and standby-generator components are often referred to as emergency power systems.

12.1. UPS designs

The general categories of modern UPS systems are:

- on-line,
- line-interactive, and
- standby.

An on-line UPS uses a "double conversion" method of accepting AC input, rectifying to DC for passing through the battery (or battery strings), then inverting back to AC for powering the protected equipment. A line-interactive UPS maintains the inverter in line and redirecting the battery's DC current path from the normal charging mode to supplying current when power is lost. In a standby ("off-line") system, the load is powered directly by the input power and the backup power circuitry is only invoked when the utility power fails. Most UPS below 1 kVA are of the line-interactive or standby variety which are usually less expensive.

For large power units, Dynamic Uninterruptible Power Supply are sometimes used. A synchronous motor/alternator is connected on the mains via a choke. Energy is stored in a flywheel. When the mains power fails, an Eddy-current regulation maintains the power on the load. DUPS are sometimes combined or integrated with a diesel-genset.

Fuel cell UPS have been developed in recent years using hydrogen and a fuel cell as a power source, potentially providing long run times in a small space. A fuel cell replaces the batteries used in other UPS designs.

12.1.1. Rotary UPS systems

Rotary uninterruptible power supply equipment use a motor-generator system to create a perfect sine wave output. These units can be configured as:

- a motor driving a mechanically connected generator,
- a combined synchronous/synchronous motor/generator wound in alternating slots of the field and stator, or
- a Hybrid Rotary UPS utilizing a Rectifier and Inverter as found in traditional double conversion UPS with the addition of a motor being driven by the inverter and coupled to a generator. Here the motor generator can be synchronous/synchronous or induction/synchronous.

The motor side of the unit in cases 2 and 3 can be driven directly by an AC power source (typically when in inverter bypass), a 6-step double-conversion motor drive, or a 6-pulse inverter. Case 1 uses an integrated flywheel as a short-term energy source instead of batteries to allow time for external, electrically coupled gensets to start and be brought online. Case 2 and 3 can use batteries or a free-standing electrically coupled flywheel as the short-term energy source. Sometimes, in case 1, a diesel engine can be run up to speed and then mechanically coupled to the generator, or the flywheel itself can be used to start the diesel engine (which is mechanically coupled as required to the flywheel and generator).

The life cycle of these units is usually far greater than that of their static siblings, up to 30 years or more. But, they do require periodic downtime for mechanical maintenance (ball bearing replacement), while solid-state designs, using batteries, do not require downtime if the batteries can be hot-swapped, which is usually the case for larger units.

12.1.2. Off-line Standby Power Supply (SPS)

The Off-line Standby Power Supply (SPS) offers the bare bones power protection of basic surge protection and battery backup. Through this type of SPS a user's equipment is connected directly to incoming utility power with the same voltage transient clamping devices used in a common surge protected plug strip connected across the power line. When the incoming utility voltage falls below a predetermined level the SPS turns on its internal DC-AC inverter circuitry, which is powered from an internal storage battery. The SPS then mechanically switches the connected equipment on to its DC-AC inverter output. The switch over time is stated by most manufacturers as being less than 4 milliseconds, but typically can be as long as 25 milliseconds depending on the amount of time it takes the SPS to detect the lost utility voltage.

Users selecting this type of an SPS must be aware that their computer equipment, as well as most electronic equipment is designed for use in their country. Most Off-line SPS products on the market today only provide a sine wave output when operating normally from the utility line. When they switch to their internal DC-AC inverter, they may only provide a square wave, modified square wave or quasi-sine wave, not a pure sine wave. In many cases, equipment may appear to operate normally on these waveforms, but over time may be damaged by them. It is important that lighting loads be tested. Certain electronic ballasts may not function correctly due to the poor mains waveform and the power factor correction-capacitor in switch start ballasts may cause excessive current drain.

When only minimal protection is needed, it is always best to select an SPS or UPS that states it has an inverter with a true sine wave output. Most off-line SPS units will not be capable of accepting additional battery packs for extended battery operation. To keep the cost down and prevent overheating, their inverters are designed to only operate as long as the internal battery capacity allows. Units of all three design types typically provide from 5 to 15 minutes of battery back-up time when loaded to their full output capacity. Slightly longer backup times can be achieved by overrating the SPS or UPS size.

12.1.3. Line-interactive UPS

The Line-interactive UPS offers the same bare bones surge protection and battery back-up as the standby, except that it has the added feature of minimal voltage regulation while operating from the utility source. This line-interactive design came about due to the SPS inability to provide an acceptable output voltage to the connected equipment during “brown-out” conditions. Interestingly, however, many standby models now have a voltage regulation feature. A “brown-out” happens when the utility voltage remains excessively low for a sustained period. Under these conditions the off-line SPS would go to battery operation and if the brown-out was sustained long enough, the SPS battery would become fully discharged, turn the power off to the connected equipment and not be able to be turned back on until the utility voltage returned to normal. To prevent this from happening a voltage regulating transformer was added, hence the term line-interactive was born. This feature really does help, as low voltage utility conditions are common. The down side for this design, most of the units available have to switch to battery momentarily when making transformer voltage adjustments and this can be a bit annoying in a quiet home office on a bad power day. Again when selecting a Line-interactive UPS it is always best to select a model with a true sine wave output. Several manufacturers have models available that will accept extended battery packs to provide additional battery runtime. This type of UPS typically costs more than the off-line type, but is worth the additional cost.

12.1.4. On-line UPS

The On-line UPS provides is ideal for environments where electrical isolation is necessary or for equipment loads of greater than 10kW. It does typically cost more, but like all electronic equipment today the cost is coming down as the technology advances. The true advantage to the on-line UPS is its ability to provide an electrical firewall between the incoming utility power and sensitive electronic equipment. While the off-line and line-interactive designs merely filter the input utility power, the Double-conversion on-line UPS provides a layer of insulation from power quality problems. This is accomplished with an internal transformer that isolates the input from the output. On-line UPS are generally more expensive but may be necessary when the power environment is "noisy" such as in industrial settings, in dynamic load environments, or for larger equipment loads like data centres.

12.1.5. Ferro-resonant UPS systems

Ferro-resonant units operate in the same way as a standby UPS unit with the exception that a ferro-resonant transformer is used to filter the output. This transformer is designed to hold energy long enough to cover the time between switching from line power to battery power and effectively eliminates the transfer time. Many ferro-resonant UPS’s are 90-93% efficient and offer excellent isolation.

While this used to be the dominant type of UPS, they are no longer used for common applications. Power factor correcting equipment found in newer computer systems interacts with static ferro-resonant transformers, causing potentially damaging oscillations, and the transformer itself can create distortions which yield power less acceptable than poor quality line AC. These units are still used in some industrial settings, but have mostly disappeared from use with general computer equipment. Many ferro-resonant UPS’s utilizing controlled ferro technology may not interact with power-factor-correcting equipment.

12.1.6. DC UPS systems

Many systems used in telecommunications use DC power (often 48 V). Rather than converting AC to DC to charge batteries, then DC to AC and then convert it back to DC again, some equipment accepts 48 V DC power directly. By simply converting AC power to DC power and adding batteries to the DC side, one or more conversion steps can be eliminated. There has been much experimentation with DC power for computer servers, in the hope of reducing the likelihood of failure and the cost of equipment. Because there is more current to transfer the same amount of energy at the lower DC voltage, larger conductors are needed, and more energy is lost as heat. Eliminating a conversion step may seem more reliable, but the ability of online double conversion AC systems to entirely remove themselves from operation and transfer to bypass mode during certain UPS failures and maintenance allows for the connected servers to continue to function on unconditioned AC power while the UPS is repaired. DC-based power systems do not have this luxury, as it requires that all equipment have special DC power inputs that cannot utilize AC voltages in the event of a main DC rectifier or power distribution failure. DC has typically been the dominant power source for telecommunications, and AC has typically been the dominant source for computers and servers. Higher voltage DC (380 volts) is finding use in some data centre applications.

12.2. System selection

12.2.1. UPS power rating

Besides choosing a UPS design, there are 2 key ratings to be aware of when choosing a UPS unit. The first is the load rating, expressed as both volt amps (VA) and watts (W). Both the ratings represent the maximum amount of load that the UPS can support and the connected load typically should not exceed 80% of either. Special considerations must be made when connecting certain equipment such as printers, lighting with electronic ballasts or any type of motorized load due to their higher starting currents.

12.2.2. Run time

The second factor in deciding which unit to purchase is the amount of runtime the unit will be able to provide when the power fails. This number will vary with the load amount that is plugged into the UPS. For example, a unit may run a single computer for 30 minutes, but with 2 computers it will generally last less than half that time. Larger units typically can provide more runtime for the same load than smaller units, however that is not always the case. Some UPS units are designed to provide extended runtime or have the ability to have external battery packs connected. SABS Specifications call for durations of either one of three hours if the UPS is used to provide emergency lighting.

12.2.3. Anticipated usage

Another consideration is the anticipated usage. If the UPS is only intended to provide enough power to gracefully shut down the computers, IP-based network management or serial/USB ports on the UPS are essential. This communication will also require loading some level of software on the computer or network. If the purpose of the UPS is to provide power until a standby generator kicks in (typically under a minute), the UPS input capabilities should be matched to the generator outputs. Specifically, most standby generators made for home use (15 kW or less) and most portable generators lack microprocessor voltage-and-frequency control and may not create a smooth sine wave. This can result in voltage and frequency fluctuating by 5% or more. While most UPS systems handle voltage fluctuations gracefully, most do not handle frequency fluctuations well. A UPS with a wide "frequency window" is essential in such cases. However, this can double the cost of the unit. Only a double conversion UPS can deliver a stable output frequency when powered by an unstable input frequency.

If the UPS needs to be quiet when running from battery, or will power AC motors (as found in air conditioners and fans) or other equipment requiring a clean sine wave (such as high-end computer power supplies), a UPS that outputs a smooth sine wave is needed. For PCs and other common electronics, a quasi-sine wave waveform is acceptable.

12.2.4. Type of load

Another consideration should be based on the type of load or connected equipment the UPS will support. If the UPS is connected to ultra-sensitive electronics a rotary solution will be more suitable with 100% line to load isolation. This would not only protect the equipment from a power outage, but will also protect the connected equipment from any anomaly that comes from the utility feed.

Features to look for:

- Output frequency regulation within 0.5% (prevents connected equipment from over heating)
- Electromagnetic interference (EMI)
- AC noise suppression (noise filtering).
- Reasonable cost for replacement batteries.

If the UPS outputs a sine wave, a high quality unit will feature a voltage regulating transformer.

12.3. UPS Maintenance

12.3.1. UPS maintenance

UPS modules are designed to provide maximum power in minimum footprint; consequently, maintenance spaces are generally cramped. UPS design varies considerably among manufacturers, and specialized knowledge is necessary to identify inspection and maintenance points within the unit.

The maintenance team should:

- inspect the interior of the unit for corrosion and heat damage,
- record and adjust the battery-charger float voltage,
- calibrate metering and protection functions,
- tighten power connections and
- clean the module, and performs other unit-specific maintenance activities as recommended by the manufacturer.

A battery run-down test must be performed during which the technician should perform thermal scans on internal power connections and components to identify poor or marginal connections. Scanning should be repeated during the recharge cycle to ensure that rectifier components are adequately scanned.

12.3.2. Battery maintenance

Only trained personnel should perform maintenance on UPS batteries, which generate voltages that are dangerous and can even be lethal. Battery racks and cabinets often provide little working space for connecting probes or tightening bolts, and unintentional contacts can easily happen. Sealed UPS batteries look similar to the more familiar and benign automobile batteries, which can make the danger easy to overlook. The requirements of an effective battery maintenance program depend to a degree on the type of batteries that are installed.

Flooded-cell batteries, whose electrolyte is visible through the glass container, generally deliver higher performance for a greater length of time, but they have higher initial costs and advanced maintenance requirements.

Valve-regulated batteries, also known as sealed or maintenance-free batteries, have lower costs up front and require less maintenance than flooded-cell batteries. However, they also have higher internal resistance and shorter life. Flooded-cell batteries can last 20 years, while the average expected lifetime of valve-regulated batteries is 7 years.

An effective battery maintenance program must include regular inspections, adjustments and testing of UPS batteries, with thorough records of all readings. Trained technicians should:

- visually inspect batteries and racks monthly for signs of corrosion or leakage,
- measure and record the float voltage and current of the entire bank,
- note the electrolyte level in each cell,
- record the voltage and electrolyte density of selected battery cells and
- log the ambient temperature.

They also should verify that spill-containment materials are available, that emergency wash stations are operational, and that the battery-room exhaust system is functioning.

Quarterly maintenance typically includes monthly inspection items, in addition to recording the voltage readings for each cell and electrolyte temperature of selected cells. Annually, technicians should document inter-cell resistance readings for each cell connection and the internal resistance of each cell. Annual maintenance also involves re-torquing connecting bolts and measuring the exhaust airflow with remedial action, if required. They also should perform annual maintenance procedures after a high-current discharge.

Storage batteries have limited life, usually showing a slow degradation of capacity until they reach 80 percent of their initial rating, followed by a comparatively rapid failure. The number and depth of discharge cycles, ambient temperature and charging characteristics affect battery life. The combined effect of these factors is difficult to quantify, so managers need a means to determine when a battery is near the end of its useful life in order to replace it while it still works and before the critical load is left unprotected.

The only sure way to determine battery capacity is to perform a battery run-down test. The module is taken off line, connected to a load bank and operated at rated power until the specified run time elapses or the unit shuts down due to low battery voltage. If the observed battery capacity is 80 percent or less of its rated capacity, the technician should replace the battery.

Thermal scanning of battery connections during the battery run-down test will identify loose or marginal connections. This test is normally a manager's only opportunity to observe the battery during an extended, high-current discharge. Scanning should take place during both discharge and recharge cycles.

12.4. Replacing batteries

In order to provide the desired protection, UPS units must be properly maintained. Sealed lead/acid batteries have a useful lifetime of 3–5 years. In determining when to replace batteries, it is important to remember that the batteries can be completely bad after 3–5 years and lose their ability to hold a charge gradually over that time. If a UPS started with 1 hour of runtime for the connected load, after 1 year, it may only provide 45 minutes of backup time. Battery failure can also be caused by temperature. If the application requires the battery to operate properly at temperatures exceeding 25 °C, use gel batteries. This will allow the UPS to work in temperatures between -40 to +70 °C.

13. Connection of alternative power sources

The electricity supply crisis (2008) led to panic buying of generators to alleviate the “load shedding” scourge. The generators were, in most cases, hastily connected to distribution boards without transfer switches. This led to many disastrous incidents including:

- compromised earthing causing electrocution,
- generator feedback onto supply grid causing over-current conditions and
- generator destruction when ESKOM power was restored.

It is vital to heed warnings posted by the ECA (SA) stating:

“The onus rests on you, as homeowner, to ensure that the electricity in your house does not pose a threat to you, your family, any other person or animal, or the property. This also places the responsibility on you to prevent any hazardous situation that may trigger an electrical incident.

The electrical compliance certificate has no expiry date but if any additions, modifications or alterations are carried out to your installation you will require an additional certificate for such work or, if necessary, a new certificate for the entire installation.

Failure to acquire such additional certificate will mean that the entire installation is not certified and may render the original certificate invalid. Should an incident occur, all involved parties will be investigated and the homeowner could attract liability if the installation is not safe or is not being correctly used. It could also invalidate the insurance on the property.”

Temporary connections using extension cables and the like are therefore not desirable. It is also important for any alternative power supply to comply with the new SANS 10142-1 (The wiring of premises Part 1: Low-voltage installations).

Important aspects to the new SANS 10142-1 Standard include:

Notices: 7.12.2 - Where any form of alternative supply (emergency supply, UPS, etc.) is connected to an electrical installation, a notice to this effect shall be displayed at the main switch of the installation.

Changeover: 7.12.2.5 – Where the alternative supply is intended to provide an alternative supply to an installation or part of the installation, the changeover device shall disconnect the mains supply before the generating set is switched in. The changeover-switching device shall be interlocked in such a way that the main supply and the alternative supply cannot be connected to the installation or part of the installation at the same time.

Earthing requirements: 7.12.3.1.1 – Protection in accordance with the requirements of 6.7 shall be provided for the electrical installation in such a manner as to ensure correct operation of the protection devices (earth leakage, over current etc.), irrespective of the source of supply or combination of sources of supply. Operation of the protection devices shall not rely upon the connection to the earthed point of the main supply when the generator is operated as a switched alternative to the main supply (i.e., the generator must have its own earth connection).

Protection against overcurrent: 7.12.4.1 – Overcurrent protection and isolation shall be located as near as possible to the output terminals of each alternative supply unit, except where the cable connecting the unit is regarded to be within a fault-free zone of the distribution board where protection is installed and it is mechanically protected. The circuit breaker magnetic characteristic shall have a low threshold value in view of the high impedance of the generator (or in the case of a static UPS, the current limiting characteristics).

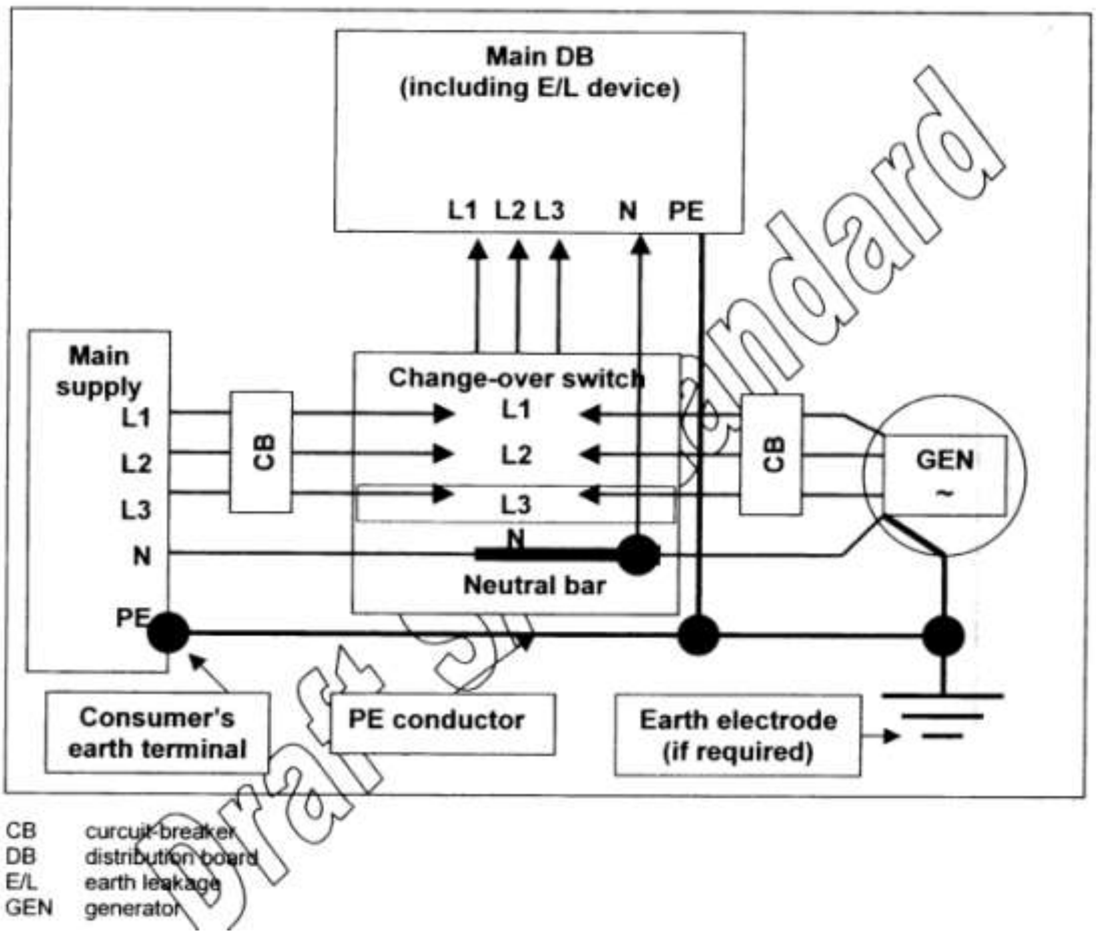
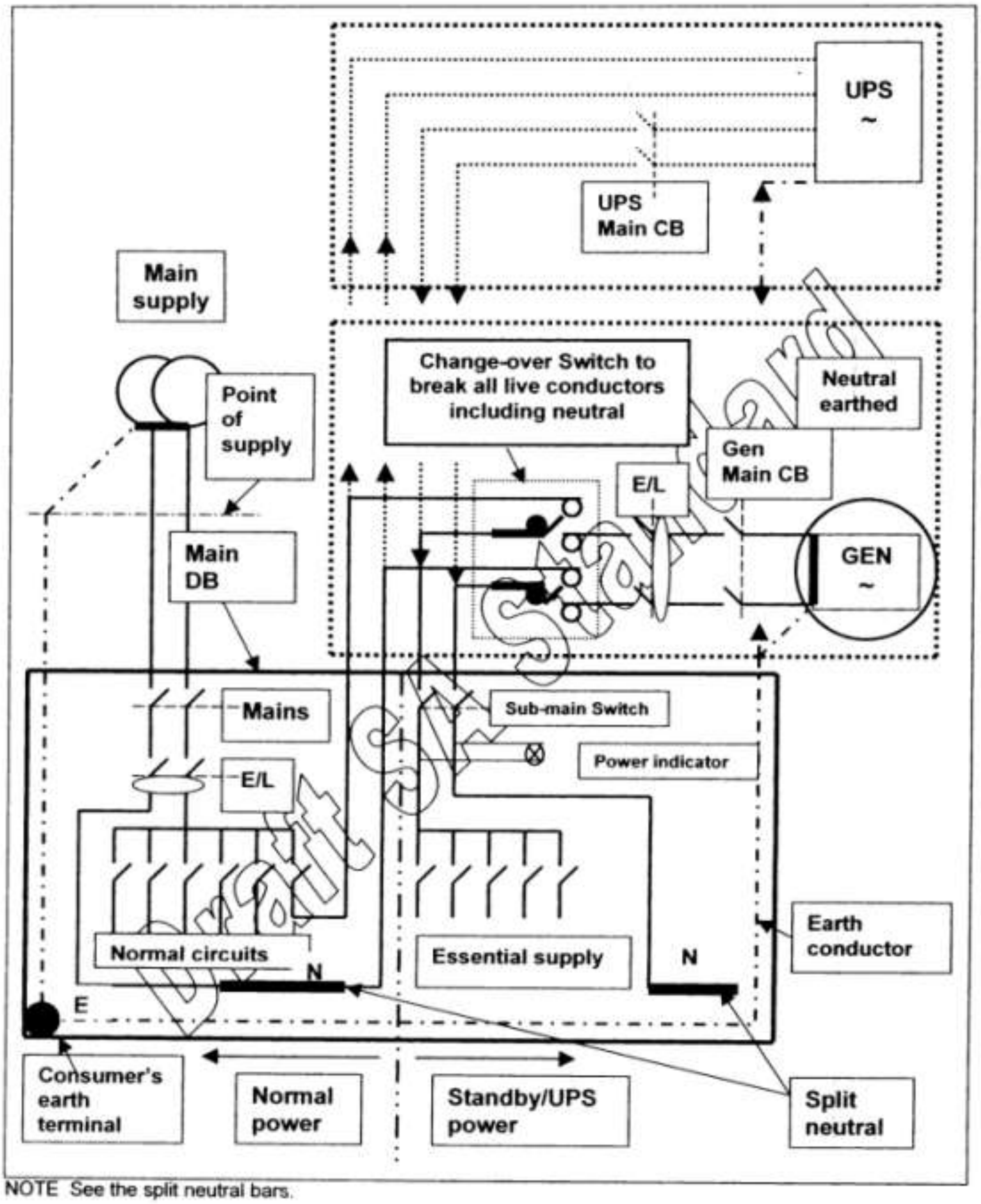


Figure 24

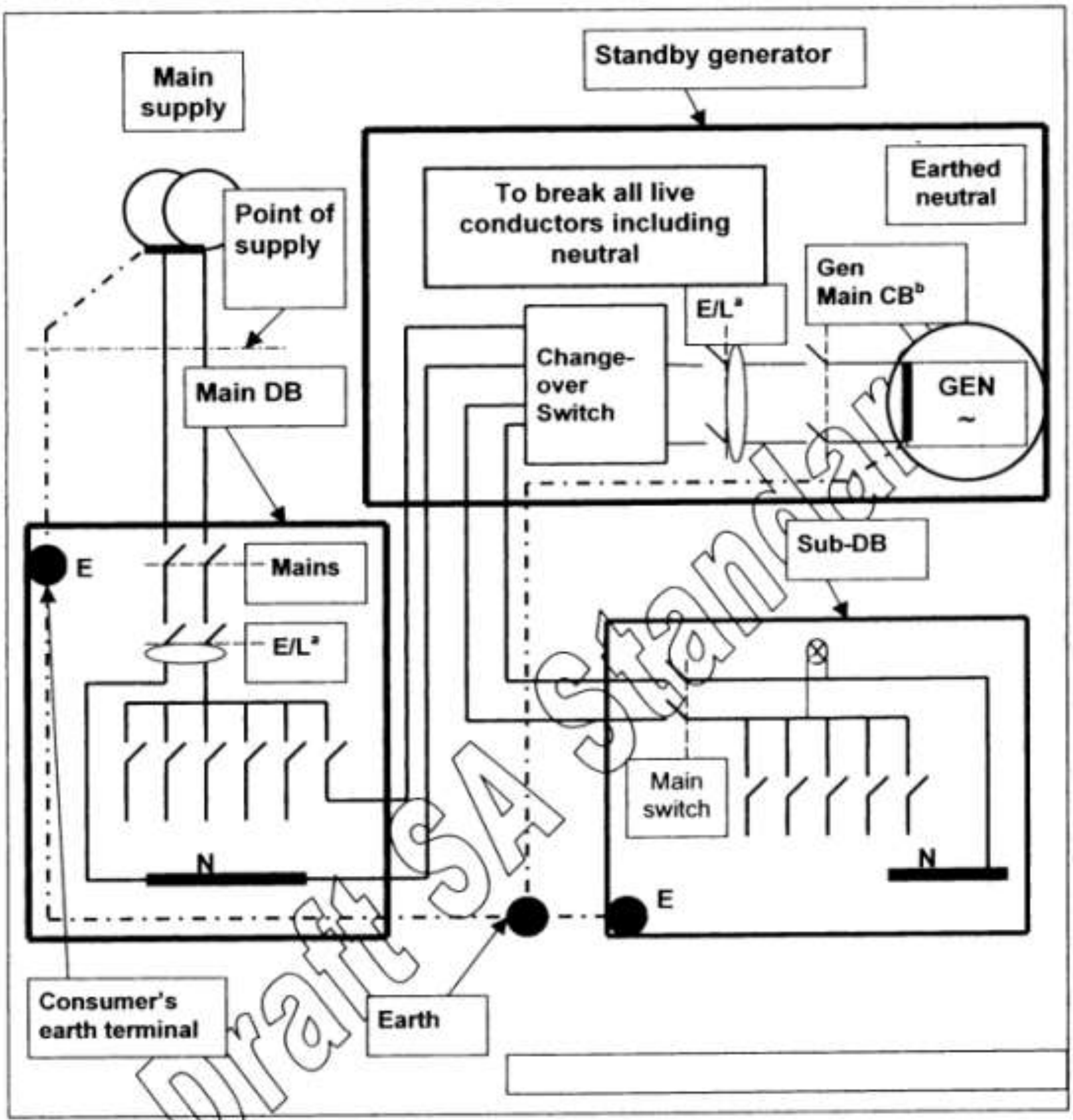
Figure 24 shows the changeover switch connection where standby power feeds in at the main supply. Note the earth electrode at the generator and the permanent earth connection between the generator and the DB.



NOTE See the split neutral bars.

Figure 25

Figure 25 shows the changeover switch connection where the standby power feeds into a section of the main DB. Note the earth connections and the earth leakage switches.



CB circuit breaker
DB distribution board
E/L earth leakage
GEN generator

Figure 26

Figure 26 shows the changeover switch connection where the standby power feeds in after the main DB into a sub-DB. Note the earth connections and earth leakage switches.

13.1. Safety Practices

- Treat all installation as live even during a power outage.
- Never run a generator in an enclosed area.
- Keep all guards and shields in place to protect the operator from moving parts.
- Always check for downed power lines or damaged circuits before connecting a generator.

- Use extreme caution, especially under wet conditions.
- Never refill (fuel) a generator engine that is hot or running.
- Never shut off the generator under load.
- Never store gasoline indoors or near the generator where gas vapours could be ignited by a spark from the generator.

14. Legal requirements and guidelines

It is important to be aware of legal requirements before undertaking an emergency escape lighting design. Two main instruments are of interest to emergency lighting:

- The Occupational Health and Safety Act (OHS Act) and
- SABS Specifications

The OHS Act, an act of parliament states that it is illegal not to have emergency lighting in the workplace in areas where failure of the normal mains supply may present a danger through low visibility.

The SABS has a mandate to draw up specifications controlling the design of appliances etc. in order to ensure the health and safety of the general population. A compulsory specification (VC 8055) has been issued that calls various safety standards (including SANS 1464 Part 22) making it illegal for emergency lighting products not to comply with certain levels of safety and performance. Interestingly, because the emergency lighting forms part of safety equipment, it must not only be designed to prevent shock or a fire hazard, it must also provide correct light levels, lighting duration and other technical levels of performance.

In addition, although not compulsory, the SABS offers internationally acceptable design guidelines to ensure the functionality and, probably more importantly for cash strapped budgets, cost effectiveness of an emergency lighting solution.

15. Occupational Health and Safety Act

(OHS Act: Act 85 of 1993)

15.1. General

The OHS Act is a statutory law prescribing minimum standards necessary to ensure the safety of workers in the workplace. It is illegal not to comply with its provisions and contraventions are punishable by a fine and/or prison sentence. In terms of the Act, emergency lighting must be provided to enable safe egress in the event of fire or power outages and must be kept in good working order.

The following excerpts were taken from the section titled: “Environmental Regulations for Workplaces 1987”:

15.2. Emergency lighting required

The act states that emergency lighting must be provided in areas where there is no natural light or where persons habitually work at night. The minimum light level required is 0.3 lux at the floor level.

Further, an illuminance of not less than 20 lux shall be provided where it is necessary to stop machinery, shut down plant, where dangerous materials are present or where dangerous processes are carried out.

15.3. Emergency lighting performance requirements

- The emergency lighting must be activated within 15 seconds
- The duration shall be long enough to ensure safe evacuation of all indoor places
- The emergency lighting must be kept in good working order and tested for efficient operation at least every three months
- Directional emergency luminaires must be mounted at least 2 m above floor level and aimed downwards, below 45 degrees from vertical.

16. Building Regulations (SABS 0400-1990)

(Code of Practice for The application of the National Building Regulations)

16.1. General

This code of practice sets out the requirements to ensure that buildings will be designed and built in such a way that people may live and work in a healthy and safe environment. As such, it includes workplaces, entertainment, restaurants, places of worship, learning institutions, hospitals and shops (for more than 25 people). The following excerpts are from sections TT29 and TT30:

16.2. Marking and signposting

Any building having emergency routes shall be clearly marked and signposted to indicate the direction to be travelled in the case of any emergency, the size and positioning of the required marks shall be determined by the local authority.

The marking or signs must comply with SABS 1186: Symbolic safety signs (this Standard defines the logo, colours and performance (where relevant) of the sign. In the case of an auditorium or hall, a sign reading “EXIT/UITGANG” shall be displayed over any exit doors with letters not less than 150mm high.

Emergency exit signs shall be illuminated by not less than 50 lux.

In any building occupied during hours of darkness and with a population exceeding 100 persons then emergency sign duration must be not less than 120 minutes.

The signs must be protected against the effects of fire for a duration of 120 minutes. This requirement inherently prescribes signs with internal batteries or, in the case of central battery or generator sets, fire retardant wiring.

16.3. Lighting of feeder and emergency routes

Emergency routes shall be provided with artificial lighting at any time the building is occupied at an illuminance of 50 lux on a horizontal plane 100 mm above the floor (during normal mains conditions).

In any building of more than 100 persons the emergency route must be illuminated by emergency lighting whose power is independent of the mains power:

- for not less than 60 minutes,
- with an illuminance along the route of not less than 0.3 lux and

- a uniformity ration of not greater than 40:1.

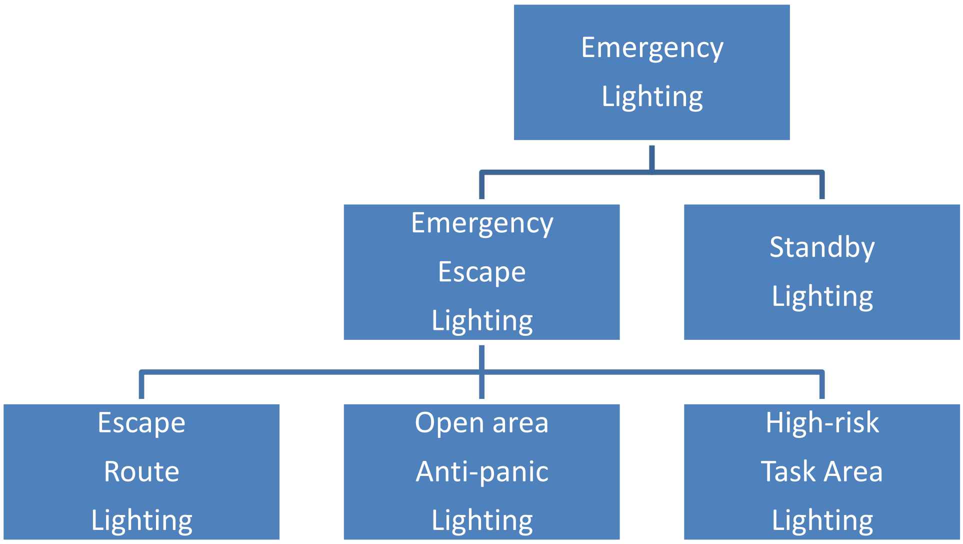
The uniformity ratio is the ratio between the brightest and darkest points along the escape route. These requirements indicate a preference for many, low light output, emergency lights rather than a few high light output units. This improves safety because failure of a few emergency luminaires will not adversely affect building evacuation.

17. Emergency Lighting Code of Practice (SABS 0114-2)

(SABS 0114-2:2002 Code of practice for Interior Lighting. Part 2: Emergency Lighting)

17.1. General

This Standard deals with the design of an emergency lighting system. It describes emergency luminaire positioning for escape routes, open areas and high-risk task areas. Choices of appropriate systems, exit signs, logbooks and servicing are also covered.



The above chart shows the various categories of emergency lighting. Standby lighting is defined as lighting provided to enable normal lighting levels and hence normal activities to be continued in the event of a power failure, and so falls outside the scope of this work. Emergency escape lighting is defined as lighting provided to enable safe egress from a building in the event of a power failure or fire and hence much lower lighting levels are required. It would be more appropriate to define the illuminance as orientation lighting because all that is required is for the occupants to safely negotiate their way to an escape route, follow the signs and exit the building.

17.2. Emergency escape lighting

Luminaires should be mounted at a height 2 to 2.5 m above floor level. All signs indicating the escape routes shall be illuminated to indicate an unambiguous path out of the building. Where an emergency exit is not in direct view, an illuminated directional sign shall be provided to assist progression. An escape lighting luminaire shall be sited above each exit door, where there is potential danger and at safety equipment providing a minimum illuminance of 5 lux out to a horizontal distance of 2 m.

Escape lighting luminaires shall be positioned at the following locations:

- At each escape exit door
- Over stair wells
- Near any other change in level
- Where mandatory safety signs are installed
- At each change in direction
- At each corridor intersection
- Outside the final exit
- Near each first aid post
- Near each piece of fire-fighting equipment

In order to identify colours on safety signs the minimum colour rendering index shall be 40. The emergency lighting duration of any emergency luminaire shall be at least 60 minutes.

The disability glare shall be kept low within the field of vision. The disability glare specification limits light emitted between 60 and 90 degrees from the vertical axis.

The luminaires should be mounted as low as possible but not below 2 m above floor level if possible (car parks may be a problem). If they are mounted below 2 m then they must be mechanically protected.

The emergency lighting shall be activated not only on complete failure of normal power but also in the case of a localised failure if such a failure would present a hazard, for example, if a single sub-circuit on a stairway were to fail.

The illumination along an escape route should come from more than one luminaire so that failure of one luminaire does not plunge the entire escape route into complete darkness.

17.3. Escape route lighting

The general requirements for escape route lighting are:

- Minimum illuminance of 0.3 lux
- For retirement centres at least 3 lux is recommended
- Maximum uniformity ratio of 40:1
- Activation within 25 to 30 seconds with full illuminance within 60 seconds

The response time requirement was 15 s (in line with the international figure) but has been extended here in South Africa possibly to enable the use of generator sets.

17.4. Open area anti-panic lighting

General requirements:

- Illuminance of at least 0.5 lux at empty floor area up to a height of 0,5 m on the perimeter
- Maximum uniformity ratio of 40:1
- Response time within 30 seconds with full illumination within 60 seconds

The response time here was also15 s (in line with the international figure) but has been extended here in South Africa possibly to enable the use of generator sets.

17.5. High risk task area lighting

General requirements:

- Illumination of at least 10% of normal lighting or 20 lux, whichever is greater
- Maximum uniformity ratio of 10:1 within 5m of task
- Duration of at least 30 minutes
- Response time of at least 0.5 seconds

17.6. Siting of additional escape lighting

- External areas in immediate vicinity of exits
- Lift cars with a duration of at least three hours
- Toilets, lobbies and closets
- Motor generator, control and plant rooms
- Cover car parks

17.7. Choice of an appropriate system

- Exit signs shall be maintained in premises where people are unfamiliar with layout
- Maintained emergency lighting shall be used in dimming circuits
- Three hours duration for any building higher than 10 storeys and underground areas
- Three hours duration for shopping malls

17.8. Emergency exit signs

- Shall be used to ensure that the emergency route can be easily recognised
- Comply with 1186-3 (colour and performance)
- Shall be illuminated at least 50% within 15 s and full brightness within 60 s. Internally illuminated signs (in compliance with SABS 1186-3) shall be displayed at all the exit doors of auditoriums or halls. The duration of the exit signs shall be at least equal to the duration of the emergency escape lighting.
- Safety colour at least 2 cd/m^2 in all relevant viewing angles.
- Uniformity ratio across sign not less than 10:1
- The maximum viewing distance of an emergency exit sign shall be determined from the equation:

$$D = S \times P$$

Where *D* is the maximum viewing distance in metres, *P* is the sign height in metres and *S* is a constant (100 for externally illuminated signs and 200 for internally lit signs)

- Signs shall be positioned so their base is between 2 and 2.5 m from the floor level.

17.9. Emergency escape lighting system drawings and log book

- Drawings of emergency lighting installations shall be retained on the premises and regularly updated to reflect changes.
- A log book shall contain date of commissioning, date of each inspection and test, defects and remedial action, alterations and tests of duration
- On completion of any inspection as required in the OHS Act (Act 85 of 1993) a periodic inspection and test report shall be supplied to the person responsible for the premises.

The log book shall contain the following information:

- Date of commissioning
- Date of each periodic inspection (see OHS Act)
- Date and brief details of service, inspection or test
- Date and brief details of any defects and remedial action taken
- Date and brief details of alterations to the emergency lighting system
- If self-test devices used then description and performance of that device
- Date and brief details of annual tests for duration, illumination and system recovery after testing.

17.10. Servicing

Regular servicing of an emergency lighting system is essential. It is even more important now that the OHS Act demands that systems be maintained.

17.10.1. Monthly checks

A monthly inspection shall be carried out in accordance with a systematic schedule detailing inspection criteria and required actions. A status report of self testing devices (if used) shall be complied indicating system status, error codes and required action. Tests on non self testing devices shall not exceed ¼ of the rated duration and check all devices to ensure function both during and after test. In the case of central battery systems the system monitors, if fitted, shall be checked or system functionality must be determined. Generator sets are required to be tested for at least one hour.

17.10.2. Annual checks

Each emergency luminaire and sign shall be tested for its full duration. After the supply has been restored all devices shall be rechecked for normal functioning and battery charging. Results must be recorded in the log book.

18. Safety of emergency luminaires (SANS 1464-22)

(SANS 1464-22:2004 Safety of Luminaires. Part 22: Luminaires for emergency lighting)

(Updates due in December 2010 included below)

18.1. General

This Standard deals with the safety and performance of the emergency luminaires. It prescribes marking, reliability, electrical safety, photometric performance and battery charging requirements. This is a compulsory specification (VC 8055) and so failure to comply can be prosecuted by fines and/or jail terms.

18.2. Marking

The most obvious indication of compliance to this specification is manifested by marking and labelling. Correct labelling and marking enables easy identification of emergency luminaires, their performance and replacement parts. This information benefits the end user because most relevant information is displayed on the luminaire instead on some easily lost brochure. All too often cheap hardware store variety emergency luminaires are scrambled into service to placate an angry official. This false economy usually means that the entire luminaire needs replacement when it stops working.

The following labels, stickers and leaflets are required in addition to those specified in SANS 60598-1 (Luminaires: General requirements and tests).

The rated voltage, classification and warning labels (see below for details) shall be placed in a position where they are visible after the installation of the luminaire. In the case of recessed luminaires, these labels need only be visible when the diffuser is removed.

All labels must survive the tests in SANS 60598-1 Section 3.4, which calls for the completed label to be subject to lightly rubbing the label with a cloth soaked in water for 15 seconds, allowing it to dry and then rubbing it lightly with a cloth soaked in petroleum spirit. Normal inks will not survive this test nor will permanent marker inks. Only inks from pure resin ribbons or plasticized labels will suffice.

18.2.1. Marking on the luminaire

This information must appear on the luminaire itself:

- Rated voltage
- Details of correct replacement lamps
- Rated ambient temperature (t_a) and range of ambient temperatures
- DC supply connections should be marked +/- or coloured red/black. AC supply connections shall be marked by the symbol “~”.
- Display a clear warning notice that circuits must be regarded as live even when the mains power is off
- Details of replaceable fuses or indicator lamps (if fitted)
- Details of test facilities to simulate a power failure (if fitted)
- A green dot, at least 5mm diameter, under the lamp holder of the emergency lamp in combined luminaires
- Classification label must bear the information below:

*	*	****	***

Each symbol in the segments shall indicate a number, letter or point of no indication *i.e.*, no symbol can be left blank.

The first segment indicates “Type”;
- X = self contained and
- Z = centrally supplied.

The second segment indicates “Mode of operation”;
- 0 = non-maintained
- 1 = maintained
- 2 = combined non-maintained
- 3 = combined maintained
- 4 = compound non-maintained
- 5 = compound maintained
- 6 = satellite

The third segment indicates “Facilities”;
- A = including test devices
- B = including remote rest mode
- C = including inhibiting mode
- D = high-risk task area luminaire

The fourth segment indicates “Duration” for self-contained luminaires;
- *10 = ten minutes duration
- *60 = one hour duration
- 120 = two hours duration
- 180 = three hours duration

The following example shows the marking for a combined, self-contained, one hour duration (say 4 x 18W recessed with one lamp on emergency) luminaire:

X	**1**	********	***60**

An example of required emergency luminaire labelling is shown in Figure 27 below. It is imperative that all emergency luminaires carry such labelling otherwise they do not comply with SANS 1464:22 and are thus illegal.

Figure 27

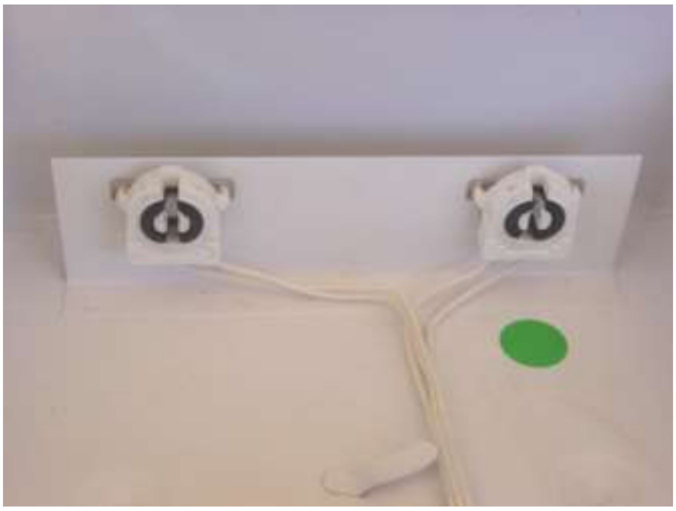


Figure 28

An identifying green dot (see Figure 28) of at least 5 mm diameter must be affixed under the emergency lamp so that it is visible whist the lamp is being replaced.

18.2.2. Marking on batteries (for self contained luminaires)

This information must appear on the battery pack. A difficulty arises when the dates have to be written on the labels and then still satisfy the wiping test because even indelible ink smudges. In this case, it is best to print the labels bearing all the months and a few year numerals and then during commissioning the date can be logged by simply scratching out the relevant date. The information required on the battery pack is:

- Details of correct battery replacement type and rated voltage
- Date of manufacture
- Date of commissioning
- Maximum case temperature (t_c)

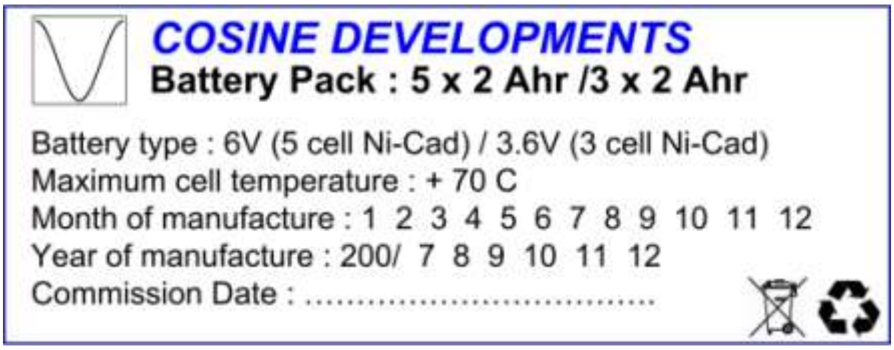


Figure 29

Figure 29 shows an example of a battery label. Note that the manufacture date is captured by scratching the relative month and year. In this way, no surface treatment is required thereafter to ensure indelibility.

18.2.3. Instruction leaflet

- Batteries must be replaced when the measured duration is less than the rated emergency duration
- Correct lamp replacement for all lamps in combined luminaires
- Details of test facilities or self test emergency related instructions, if provided
- Details of rest mode, if provided
- Details of connection leads between a compound luminaire and satellite luminaire or central battery connections, to limit the volt drop to 3% of the rated voltage
- Rated light output of the luminaire

18.3. Construction

Safety in construction shall be ensured by complying with SANS 60598-1. Included here is insulation strength and electric strength etc..

In centrally supplied luminaires, adequate separation between normal (mains) and emergency (usually dc) shall be ensured by double insulation, reinforced insulation, earthed screen or other means. The use of basic insulation for both circuits fulfils the requirement.

Batteries shall be protected against excessive discharge currents by the incorporation of a safety device.

The battery case temperature shall not exceed the stated (t_c) temperature in an ambient temperature of 25 ^{o}C.

In self-contained luminaires, lead-acid and nickel-cadmium batteries shall be protected against polarity reversal of individual cells and against harmful complete discharge. For lead-acid batteries low voltage cut-off shall be:

- 12 V batteries must be 10.5 V
- 6 V batteries must be 5.1 V.

For nickel cadmium batteries, the cut-off shall be 0.8 V per cell.

18.4. Endurance and thermal test

18.4.1. Endurance test

Mounted on a similar mounting surface and at the same orientation as used in service and at an ambient temperature of t_a + 10^{o}C (where t_a is 25^{o}C unless otherwise marked on the luminaire).

The mounting is important especially with bulkhead type fittings because heat rise within the luminaire are more dramatically affected by the direction of the convection currents from the lamps and surface dissipation. The worst-case orientation is usually ceiling mounting against surfaces with a high thermal resistance such as wood or ceiling board. In this case a significant portion of the whole surface dissipating area is insulated and can cause significant increases in internal temperature.

The test shall last 390 hours consisting of ten cycles of 36 hours (30 hours with mains on and 6 hours in emergency mode) and a final cycle of 30 hours to charge the batteries fully to be ready for the next test.

Afterwards the luminaire must function and a visual inspection shall reveal no damage such as cracks, scorches or deformation.

Thereafter the luminaire shall survive 50 supply switchings of 60 seconds mains on and 20 seconds mains off *i.e.* emergency power.

In the case of emergency products having an inherent delay after the restoration of power the 50 switching cycle test may have to be modified in duration to allow additional battery charging.

Compliance shall be checked by inspection.

Note that the Standard allows for chance failure of components including the lamp. By chance failure, it allows abnormal failure due to, for example, a defective lamp. It should be noted that, as most emergency circuits cause rapid lamp ageing, the lamp must survive this test and still be functional.

18.4.2. Thermal test - Normal operation

During normal operation, no part of the luminaire (including the lamp), the wiring or mounting surface shall attain a temperature that would impair safety.

Again, the mounting orientation must be the most onerous. The mains voltage is set to 244V (1.06 x 230V) and the ambient temperature should preferably be 25^{o}C. For measurement of the temperature rise of the emergency control unit (t_c) then the mains voltage must be set at 230V.

Measurements shall be taken when all temperatures have stabilised or when temperatures are changing less than 1^{o}C per hour.

The temperature of the emergency control unit shall not be more than 2^{o}C above the rated t_c value or, if no t_c value is given then the temperature of its case should not exceed 50^{o}C.

The temperature of unmarked components, i.e. the battery pack (in self-contained emergency luminaires), must not exceed 50^{o}C. This measurement cannot be underemphasised and is especially important in bulkhead type emergency luminaires.

This test is to be carried out in both normal and emergency modes until complete battery discharge (in self-contained units). In the normal mode the battery charger may cause over-heating and during the emergency mode the emergency driver circuitry may over-heat and, at high discharge currents, the battery temperature may also rise. Complete battery discharge is given by 1 V/cell in the case of nickel-cadmium batteries and 1.75 V/cell (or 10.5 V on a 12 V battery) for lead-acid batteries.

18.4.3. Thermal test - Abnormal operation

This test in included to ascertain the luminaire performance during high mains voltage and lamp fault conditions, which may arise at the end of lamp life. The test must be conducted at 253 V (or 1.1 times rated mains voltage) and with a variety of lamp faults including:

- Starter short circuited (where applicable)
- Lamp rectification (see below)
- Lamps removed
- One electrode open circuited
- Electrodes intact but tube glass cracked

The lamp rectification is the most difficult to simulate (details are given in Annex C of SANS 60598-1) buts its results may well be the least onerous for emergency lighting circuitry using the standard current fed oscillator.

Tests shall be conducted for both normal and emergency modes until complete battery discharge (in self-contained units). Complete battery discharge is given by 1 V/cell in the case of nickel-cadmium batteries and 1.75 V/cell (or 10.5 V on a 12 V battery) for lead-acid batteries.

Another demanding test is the battery short circuit test. Here the batteries are removed and replaced with a short circuit still with the mains voltage at 253 V. The temperature of the emergency control unit casing shall not exceed t_c + 10^{o}C or, if no t_c value is given, 60^{o}C. After the test, the battery charger must function normally.

18.5. Photometric performance

The luminaire shall provide rated lumen output claimed by the manufacturer during emergency mode for 1 minute after failure of supply and continuously to the end of rated duration. A luminaire for high-risk task area lighting shall provide rated light output within 0.25 seconds after mains failure.

The luminaire light output is calculated by measuring the light output on a plane 2 m below the luminaire in normal mode and then in emergency mode. The ratio of light output can then be directly scaled to suit the luminaire photometry data. Note that in normal mode all lamps must be burning (in a combined emergency luminaire).

For non-maintained luminaires, the normal light output must be measured using the appropriate mains ballast.

18.6. Changeover operation

The changeover from normal to emergency mode shall occur at greater than 0.85 times the maximum rated supply voltage (range).

18.7. High temperature operation

Self-contained emergency luminaires shall be capable of operating satisfactorily at an ambient temperature of 70^{o}C for at least half the rated duration and at 50% lumen output. This test has been included to both ensure that high temperature batteries are used and that the temperature rise of the batteries due to heat gain from surrounding components is not excessive.

18.8. Battery chargers (self contained emergency luminaires)

The battery charger in a self-contained luminaire shall charge the batteries within 24 hours when the mains supply is between 90 and 106% of the rated mains voltage and charge the batteries as specified by the battery manufacturer. This requirement ensures that batteries are charged at C/20 rate.

Transformers shall comply with SANS 61558-1. This requirement details separate winding bobbins for primary and secondary in order to prevent unsafe conditions during a transformer failure.

19. Symbolic safety signs (SANS 1186-1)

(SANS 1186-1:2004 Symbolic safety signs. Part 1: Standard signs and general requirements)

19.1. General

The Standard defines the legends and specific colours required for all safety signs.

19.2. Safety colours

The required colours associated with their respective sign meanings are given below. It is important to have standardised colours to denote various safety signs so that both workers and the general public get accustomed to their meaning. Notice also that, although often used in South Africa, red should not be used for an exit sign.

Safety colour	Meaning	Example of use	Suitable SANS 1091 colour
Red	Prohibition	Prohibition signs (and fire fighting equipment)	Signal red (A11)
Blue	Mandatory action	To wear personal protective equipment	Ultramarine blue (F09)
Yellow	Warning, risk of danger	Indication of danger or obstacles	Golden yellow (B49)
Green	Information, safe condition	Escape routes, emergency exits, first aid stations	Emerald green (E14)

The Standard specifies a suitable SANS colour and gives boundaries of suitable colours on a chromaticity chart. It is clear therefore that as long as the sign colour is more or less emerald green, etc., then it is acceptable. The Standard also specifies the contrast colour for a green safety logo is white (i.e., the background). This means that, for example, green LED edge lit transparent pendant signs are only suitable if the background wall is white.

19.3. Standard legends

Figure 30

Figure 30 shows typical exit sign logos. There are many different logos available in the marketplace and there seems to be no standardisation in South Africa.

20. Symbolic safety signs (SANS 1186-3)

(SANS 1186-3:2004 Symbolic safety signs. Part 3: Internally illuminated signs)

20.1. General

This Standard specifies the construction and performance of internally lit exit signs. It covers electrical safety, viewing distance, brightness and colour.

20.2. Safety and electrical performance

The provisions of SANS 60598-1 and SANS 1464-22 shall apply with respect to electrical safety, earthing, thermal limits, endurance, marking and electrical performance. In brief, this means that all thermal and endurance testing must be conducted and that all relevant labels and markings must be affixed.

20.3. Viewing distance

The maximum viewing distance of an internally illuminated sign shall be determined from the equation:

$$D = 200 \times P$$

Where *D* is the maximum viewing distance in metres, *P* is the logo height in metres. Also, the pictogram (logo) shall occupy between 75% and 90% of the total sign area.

20.4. Internal lighting requirements

The internal lamps shall emit a “white” light that is not detrimental to the colours of the sign. This requirement demands the use of white fluorescent lamps (which may be dimmed during emergency mode) or incandescent lamps running at full brightness during emergency mode.

The light emitted from the sign face shall be diffused and the minimum luminance of any point shall not be less than 2 cd/m^2.

The ratio of brightness across the face of the sign shall not be more than 6:1. The ratio of brightness between the background colour and the pictogram colour shall lie between 15:1 and 5:1.

The boundaries of chromaticity co-ordinates (colour tolerance) for the internally illuminated signs are broader than those specified in SANS 1186-1, especially for green. This is probably to allow for reduced colour rendering during emergency mode.

21. Automatic test systems (SANS 62034)

(SANS 62034:2007 Automatic test systems for battery powered emergency escape lighting)

21.1. General

The OHS Act requires that emergency lighting systems are kept in good working order and tested every three months. Traditionally this poses a logistics headache for the building owner because testing the emergency lighting requires switching off the mains supply to the building and then examining each emergency light and exit sign for operation. Full duration tests would require watching all the emergency fittings for up to three hours – a costly and time-consuming task. This task has been simplified by the arrival of the microprocessor; this miniature computer chip can be inserted into emergency lighting products to conduct autonomous testing and reporting.

These, so called self testing emergency lighting systems or Automatic Test Systems (ATS), have the ability to test itself, its batteries, lamp, and then to report any problems. This Standard attempts to standardise the operation and performance of self testing emergency lighting systems.

21.2. Safety and electrical performance

All parts of the ATS shall conform to the requirements of SANS 60598-1 and SANS 1464-22. That means all safety, electrical performance, photometric performance, battery charging *etc*. shall apply as with normal emergency lighting products.

The design and construction of the ATS shall ensure that only authorised personnel can change the test duration and frequency of tests.

21.3. Automatic test requirements

The ATS shall check the functional operation of the emergency lighting luminaires and associated power supplies to identify any faults that would impair their operational duty. Any faults shall be indicated or reported within 24 hours after their inspection.

21.3.1. Short duration functional tests

A functional test shall be performed at least once a month. The duration shall be sufficient to check the illumination of the lamp and shall not be more than 10% of the rated duration.

21.3.2. Full duration tests

Random automatically initiated full duration tests shall be conducted between 4 and 52 weeks after commissioning *i.e.*, at least every year.

If a mains supply failure occurs up to 24 hours before a pre-programmed rated duration test then the start of the test shall be postponed.

21.4. Test of emergency lamps

The ATS shall indicate if the emergency lamps do not operate. This test in included to ascertain the luminaire performance during lamp fault conditions, which may arise at the end of lamp life. The test must be conducted with a variety of lamp faults including:

- Starter short circuited (where applicable)
- Lamp rectification (see below)
- Lamps removed
- One electrode open circuited
- Electrodes intact but tube glass cracked

The lamp rectification is the most difficult to simulate (details are given in Annex C of SANS 60598-1) buts its results may well be the least onerous for emergency lighting circuitry using the standard current fed oscillator.

21.5. Requirements if the building is occupied during scheduled tests

Systems designed for installation in premises, which may be occupied during the duration test, shall include the following precautions to keep the security level high and to minimise disruption in the workplace:

- Schedule tests on alternate luminaires
- Enable manual initiation of the tests
- Schedule random tests

21.6. Indication of test results

The ATS shall give an indication of all test results. The result of a test shall be indicated for at least one week when the mains is present.

22. Glossary

Ballast
A fluorescent lamp cannot be simply connected to mains (or any other source) because it exhibits a negative resistance, which, without control, would eventually cause the lamp to explode. A ballast matches the lamp to its source and drives the lamp at its specified power. Old style electromagnetic ballasts required a glow starter to assist striking. New electronic ballasts or ECG do not require a glow starter and drive the lamp at high frequency.

Ballast Lumen Factor (BLF)
This is the ratio of the light output of the lamp when the ballast under test is operated at its design voltage, compared with the light output of the same lamp operated with the appropriate reference ballast supplied at its rated voltage and frequency.

Battery
This consists of a string of secondary cells to provide power during mains failure.

Battery capacity
The discharge capability of a battery, being a product of average current and time, expressed as ampere-hours over a stated duration. Note that a shorter total discharge period gives rise to a smaller available capacity.

Central Battery System (CBS)
The batteries for a number of luminaires are housed in one location in this system. The CBS usually provides power for all the emergency luminaires in one lighting sub-circuit and sometimes for all emergency luminaires in a complete building.

Combined emergency luminaire
Contains two or more lamps with at least one energised from the emergency supply and the remainder from the normal supply. The lamp energised from the emergency supply in a combined emergency luminaire is either maintained or non-maintained.

Compact Fluorescent Lamp (CFL)
This is a (usually) T5 diameter fluorescent lamp that is folded to reduce its overall size. Some versions have built-in glow starters (two pin) whilst the four pin variety behave the same as their linear counterparts.

Electronic Control Gear (ECG)
This is an electronic ballast that has less power loss than electromagnetic ballasts.

Design voltage
The voltage declared by the manufacturer to which all the ballast characteristics are related.

Emergency control unit
This is an electronic device that charges the batteries, has a relay(s) to connect the lamp to the ballast and can drive the lamp from battery power.

Exit
A way out which is intended to be used any time that the premises are occupied.

Illuminance
This is a measure of the amount of light that falls on a surface. The unit of illuminance is lux.

Kilovolt-amperes (kVA)
Denotes the power needed for inductive loads, such as motors, fluorescent lighting and other electrical devices using transformers.

Kilowatts (KW)
Electrical power term that specifies the real or heating power of the load.

Lumen efficacy
This is the efficiency at which the system turns power into visible light.

Luminaire
This is a fancy name for a light fitting.

Maintained Emergency Luminaire
A luminaire containing one or more lamps all of which operate from the normal supply and one lamp operates from both mains and the battery (during an outage).

Mounting height
The vertical distance between the luminaire and the working plane. Note that the floor is taken to be the working plane for emergency lighting.

NiCad
NiCad is actually a trademark of SAFT Batteries, however, it is now common terminology for nickel-cadmium batteries.

Non-Maintained Emergency Luminaire
A luminaire containing one or more lamps, which operate from the emergency supply only upon failure of the normal mains supply. It cannot provide normal lighting.

Normal lighting
All permanently installed artificial lighting operating from the normal electrical supply that in the absence of adequate daylight is intended for use during the whole time that the premises be occupied.

Outage
Another word for a power failure.

Rated duration
The manufacturer's declared duration, specifying the time for which the emergency lighting will provide the rated lumen output after mains failure. This may be for any reasonable period but is normally one or three hours.

Rated load
The maximum load that may be connected to the system and will be supplied for the rated duration.

Re-charge period
The time necessary for the batteries to regain sufficient capacity to achieve their rated duration.

Room index
The relationship between the height, length and width of a room used for illuminance calculations.

Self-contained emergency luminaire
A luminaire or sign providing maintained or non-maintained emergency lighting in which all the elements such as the battery, the lamp and the control unit are contained within the housing or within one metre of the housing.

Satellite or slave luminaire
An emergency luminaire without its own batteries designed to work with a central battery system.

23. On-line help

Throughout this document, the most up-to-date information available has been used by ***COSINE DEVELOPMENTS***. Some documents referred to, and some requirements, are still undergoing review, so please contact ***COSINE DEVELOPMENTS*** for advice on any changes that may affect the guidance contained in this document at info@cosine.co.za or If you require assistance with details of this document or implementation of an emergency lighting system.

Compliance with this Guide does not confer immunity from legal obligations.