

Selecting Illumination Types

When selecting types for pilot devices or signaling, the right lamp can make a big difference.

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Introduction

Illumination is a complex subject. Most users of indicating lights do not need to understand the scientific theories explaining the production and transmission of light. When specifying an indicator light, for example, your main concerns revolve around the characteristics of its light, its useful life, and both its purchase price and operating cost.

The purpose of this white paper, then, is to give you the basic background information you need to make intelligent choices when specifying indicator lights. It covers the basic types of lights in common use, how they are rated, and how environmental conditions can affect them.

Types of Lamps

Three types of lamps see common use as indicating lights. They include incandescent, neon, and light emitting diodes (LEDs). You'll see the advantages and disadvantages of each in the table below.

Table A.

Type of Lamp	Advantages	Disadvantages
Incandescent	<ul style="list-style-type: none"> • Bright • Low initial cost • Wide color options 	<ul style="list-style-type: none"> • Low/variable lifespan • Generates heat • Fragile filament
LED	<ul style="list-style-type: none"> • Bright • Long life • Low power consumption • Resistant to shock and vibration • Cool operation 	<ul style="list-style-type: none"> • Moderate viewing angle • Higher initial cost • Leakage current can cause lamp to stay ON
Neon	<ul style="list-style-type: none"> • Long life • Very low current drain • Resistant to shock and vibration • Cool operation 	<ul style="list-style-type: none"> • Minimal color options • Leakage current can cause lamp to stay ON • Requires at least 70V supply • Limited brightness • Life and output reduced on DC

Lamp Ratings

Manufacturers have adopted standardized ratings for the lamps used in pilot lights and similar indicating applications. You'll want to familiarize yourself with those standards before learning more about each of the lamp types listed in Table A.

Incandescent Lamps

Many users misunderstand the published rated life expectancies for incandescent lamps and feel those ratings are highly optimistic. Rarely do manufacturers get the data used in life expectancy tests from actual field studies. They tend instead to test their products under controlled laboratory conditions.

In one widely used test, technicians operate a number of lamps continuously at their design voltage and frequency in a shock-free and vibration-free environment until they fail. The published life rating from such a test represents not the minimum life you can expect from any single lamp, but rather the number of hours that it took 50% of a large number of such lamps to fail. That means you can expect 50% of all lamps you purchase of that type to fail before reaching their rated life.

Other manufacturers publish life ratings based on a combination of the theoretical evaporation rate of tungsten, actual life tests, and accelerated life tests in the laboratory. Lamps used under real-life conditions often face hostile and life draining environmental conditions not found in the carefully controlled setting of the test laboratory.

Neon Lamps

Neon lamps come in two basic types: standard brightness and high brightness. Although both types operate on the same principle, manufacturers rate the lifespan of each differently.

Standard brightness neon lamps emit less light over time. This dimming takes place as the lamp's electrodes evaporate and become deposited on the inside surface of the lamp's glass envelope. The lamp reaches the end of its theoretical useful life when the accumulated coating blocks 50% of the lamp's original design output.

As high brightness neon lamps age, however, the voltage needed to ionize the gas within them (the firing voltage) gradually increases. As the firing voltage approaches the line voltage, the lamp will begin to flicker and dim slightly, marking the end of its useful life.

LED Lamps

Like incandescent and standard brightness neon lamps, LEDs also show a gradual decrease in output as they age. Manufacturers consider such lamps to have reached the end of their useful lives when the brightness falls to 50% of its original value. It is generally accepted that the human eye will only notice a reduction in brightness after 50%.

Factors Affecting Lamp Life

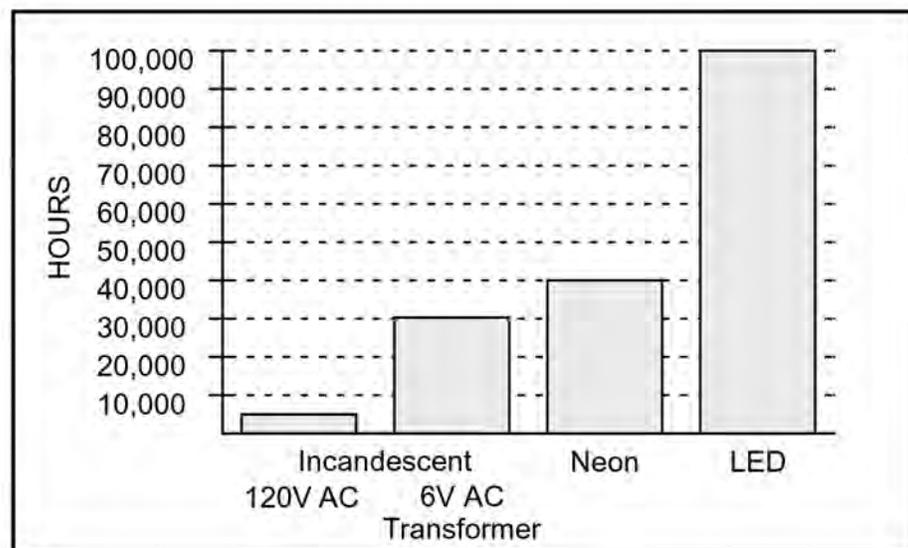
As mentioned earlier, the life you'll get from any given lamp depends in large part on the environment in which it's used. Some of the most common factors affecting lamp life appear below.

Shock and Vibration

Shock and vibration affect incandescent lamps far more than either LEDs or neon lamps.

The delicate filament inside an incandescent lamp only grows more sensitive with age. Not only does the material itself become brittle over time, but evaporation actually reduces its cross-sectional area. Even the most ordinary shock and vibration subject a filament to increasingly heavy stress, and often result in filament fracture.

Figure 1. Typical Average Lamp Life



You can minimize shock and vibration failures in the design stage by placing fixtures in protected locations whenever possible. Cushioning or other protection may also prove useful.

When using incandescent lamps in control panels or other products destined for shipment, packaging can help minimize potential damage. While transportation presents many obvious hazards, installation and maintenance of equipment may also cause damaging shock and vibration. Even slamming an enclosure door can create damaging shocks.

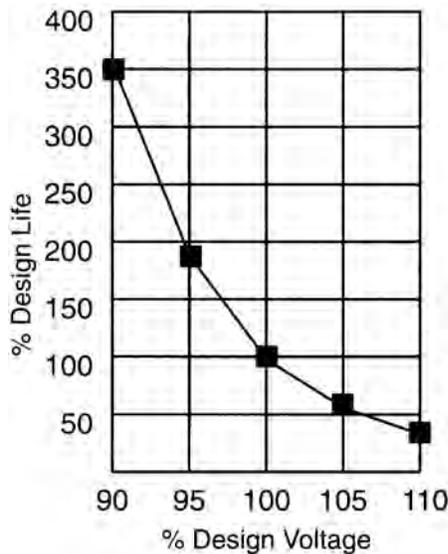
Low voltage incandescent lamps hold up best against shock and vibration. Lamps rated for 6V feature relatively short, thick filaments compared to those designed for higher voltages (which may look the same, but are actually made up of many turns of fine wire). Low voltage lamps usually offer longer life than higher voltage lamps.

Operating Voltage

Line voltage controls both the expected lifespan and the quality and quantity of light emitted by an incandescent lamp.

The life of such a lamp varies approximately inversely as the applied voltage raised to the 12th power. The light output, on the other hand, varies directly as the applied voltage raised to the 3.6th power. As a result, increasing line voltage will lead to a substantially shortened life with only a minor increase in brightness. Refer to Figure 2 for a clear idea of the relationship between voltage and lamp life.

Figure 2. Effect of Voltage on Life of Incandescent Lamps



You can see from the graph that with an overvoltage of just 5%, the actual life of a lamp will be only 50% of its rated life. Conversely, operating the same lamp with an undervoltage of 5% will result in an actual life of about 175% of its rated life. Operating a lamp below its rated voltage, however, also results in changes to both the quality and quantity of light output. It is clear that you can achieve maximum utility from a lamp by operating it at the lowest possible voltage that still delivers acceptable illumination.

Both neon and LED devices require a current limiting resistor wired in series with the lamp elements, which is usually built into the lamp itself. As a result, while supply voltage is still a factor in the performance of these lamps, it has less effect than with incandescent lamps.

AC versus DC Power

As mentioned earlier, the tungsten filament of an incandescent lamp evaporates over time. The result is a gradual reduction in the cross-sectional area of the filament, and eventual lamp failure. Lamp failure due to evaporation will occur even in the absence of significant stress or vibration.

In an ideal world the evaporation would take place at an equal rate along the entire filament. In reality, however, uniform evaporation does not occur. A number of factors lead to small variations in evaporation rates, and corresponding weak spots, along the length of a filament. They may include:

- Variations in the original cross-section of the filament.
- Trace chemical variations leading to areas with a higher or lower melting point than the bulk of the filament.
- The residual mechanical effects of cold forming and other manufacturing processes. AC power results in a more uniform evaporation rate when compared to DC power due to a destructive phenomenon known as DC notching.

Figure 3. Comparison of Filaments Operated on AC and DC Power



After AC Operation



After DC Operation

DC power causes a filament to evaporate more quickly along the grain boundaries than elsewhere. This uneven evaporation creates steps or notches in the filament surface. The resulting inconsistencies in its cross-sectional area lead to regionalized stress, and a greater susceptibility to failure. Tests show that DC-powered lamps may last only 50% as long as those powered by AC. DC notching represents a major cause of user dissatisfaction with incandescent lamps.

Research shows that the diameter of the filament has no effect on the size of the notch. Consequently, you'll experience greater problems with DC notching with higher voltage lamps because they use a finer filament, and each notch has a greater proportional effect. It will pay to avoid all DC operation at 120V. Even levels as low as 24V resulted in reduced life.

The life expectancy of neon lamps is also dependent on whether powered by AC or DC. DC-powered neon lamps may last only 50% as long as those powered by AC. You'll notice a decrease in output with DC-powered neon lamps because only one electrode will glow during use.

LEDs inherently conduct current in only one direction, so they normally operate with DC power. Operating an LED from an AC power source results in light emission only on the conducting portion of the cycle, unless a bridge rectifier is built into the lamp. You'll experience little difference in life expectancy for LEDs operated on either AC or DC if the current through the LEDs is properly controlled by a series resistor.

Inrush Current

A cold filament offers far less resistance than does a hot one. Energizing an incandescent lamp actually results in an inrush current as much as 10 times greater than normal operating current. You can minimize the detrimental effect of the resulting thermal shock by providing a preliminary warming current for lamps you expect to cycle ON and OFF frequently.

The damping effects of the resistors used with neon lamps and LEDs help minimize the effects of the inrush current.

Temperature

High operating temperatures decrease the life of any lamp. To minimize the impact of temperature, be sure to provide good ventilation, and isolate fixtures from external heat sources.

Characteristics of Incandescent Lamps

Incandescent lamps offer a number of benefits. Their brightness, variety, and low initial cost have made them a popular choice for illuminated products of all kinds. They do, however, have some characteristics which should be considered before selecting them for a given use.

- Incandescent lamps deliver more light than other types, but their output changes over time. Depending on operating voltage, that change may take the form of an increase or decrease in output. At higher than rated voltage incandescent lamps gradually brighten until their inevitable failure. Since that failure occurs without warning, an operator has no way to know for sure if an unlit lamp signifies an open circuit or a lamp failure. For example, if a lamp is used to warn the operator of unsafe operating conditions, the operator would be unaware of the equipment's status if the lamp fails. Lamp failure in this example could lead the operator to take an action that could result in damage or injury.
- Incandescent lamps may cost less to buy than other types, but those other choices may actually offer better value over the long run. The costs of frequent lamp replacement, for example, may easily offset the higher initial cost of longer lasting LEDs.
- The color of an incandescent indicator lamp depends on the color of the lens placed over it. That lens produces its colored effect by filtering out much of a lamp's output. Even translucent lenses transmit only a portion of the light that strikes them. Only a clear lens will transmit all of the light presented to it.
- When installed in clusters, as in control panels, it can seem as if incandescent lamps fail with alarming frequency. Because the lamps are so close together, the operator may believe that the same fixture is suffering repeated failures. The most economical maintenance practice calls for replacement of all the lamps in a cluster when failures begin. Such a policy will save considerable time and money.

Users of incandescent lamps often express dissatisfaction with the life of those lamps and the need for frequent replacement. As mentioned earlier, the life expectancy data published by manufacturers may contribute to this feeling because it represents life expectancy under ideal laboratory conditions. Lamps used in the real world face environmental factors that may reduce their actual life by 60% or even more.

Characteristics of LEDs

Some of the most desirable features of LEDs include long life, resistance to shock and vibration, and low power consumption. LEDs are an excellent choice where reliability is especially important.

New developments in LED materials have provided LED lamp manufacturers the ability to provide brighter lamps and more color options at a cost equal to or only slightly higher than incandescent lamps. Due to increased brightness, new lamp designs incorporate fewer LEDs and are available in red, orange, yellow, green, blue, and white. It should be noted that white LEDs have just recently been developed. It was thought that once white LED lamps were available, there would not be a need for colored LED lamps. However, the current white LED lamps do not transmit light through a colored lens as well as the same color LED lamp. White LED lamps are best used with a white or clear lens.

Like incandescent and neon lamps, LED lamps are designed for a particular operating voltage. As a rule, higher voltage LED lamps provide less illumination. This is due to the sizing requirements of the series resistors that are built into the lamps. Higher voltage LED lamps must be designed with lower currents to reduce the heat produced by the resistor, which reduces the illumination.

Special consideration must be taken when using LED lamps with PLC output modules. LED lamps turn on at lower current and voltage levels than incandescent and neon bulbs. Proper selection is important to provide compatibility. Additionally, LEDs may be susceptible to leakage current (see Appendix A — Leakage Current in PLCs on page 11).

A number of variables complicate the LED lamp selection process. LED light output is measured as luminous intensity, and most often stated in terms of millicandelas (mcd). But output ratings alone aren't enough on which to base a selection. Another variable to consider is viewing angle. A device with a relatively low mcd rating but a wide viewing angle, for example, may be more useful in a given situation than a device with a higher mcd rating that can only be seen from directly in front. In addition, the placement of the chip within the lamp assembly and the lens optics affect the usefulness of a given LED lamp. It's important to choose a supplier who understands these factors and provides a product that best suits your needs.

LEDs deliver less output over time, and rarely fail without visible warning. The gradual decline in output provides a clear indication of when a lamp needs replacement.

Ambient conditions play an important role in the life of LEDs. Temperature is especially important: a 10°C reduction in temperature may double the life of an LED.

Because LEDs are inherently DC devices, they do not suffer from DC notching. Furthermore, when proper rectification and current limitation are built into the lamps, LEDs will provide good service when powered by AC sources.

Characteristics of Neon Lamps

Neon lamps offer many advantages over other types. They are extremely rugged and resistant to failure from shock, vibration, or frequent cycling. They offer long life and low cost. Despite these benefits, neon lamps see only limited use in industrial applications.

One reason for their limited use may be their need for a power supply capable of delivering about 90V to initiate current flow. In addition, neon lamps provide only a limited amount of light within a limited range of colors. Most neon lamps produce an orange-red glow.

Neon lamps will deliver the longest life and highest light output when operated on AC. Operating a neon lamp on DC reduces its life by as much as 50% of that same lamp operating at the same RMS AC voltage.

You'll find neon lamps most useful in special applications where low current draw is an important factor. One common example is for blown fuse indicator circuits. The resistor in series with the lamp electrodes can control lamp current.

Conclusion

Based on the preceding discussion, you can see that the selection of a lamp for your own application involves a number of factors. The correct choice depends on your specific circuit needs, lamp operating characteristics, environmental factors, and overall costs. The final choice will strike an acceptable balance among these factors, and may involve a compromise between your ideal performance goals and realistic operating considerations. A knowledgeable supplier can offer valuable advice in choosing from a wide range of products to meet a variety of needs.

Appendix A - Leakage Current in PLCs

When using a programmable logic controller (PLC), leakage current in the OFF state of the output module may trigger a false ON state in LEDs and neon lamps.

Inherent in the design of some output modules of PLCs is a Triac circuit that may supply up to 5 mA of leakage current in the OFF state. A current of only 0.01 mA will sustain some LED lamps in the ON state (cause some LEDs to glow), and a 0.12 mA current will sustain some neon lamps (cause some neon lamps to glow). Some lamp designs have shunting resistors built into the lamp. For others, the leakage current must be shunted by wiring a resistor in parallel with the illuminated device to allow such lamps to turn OFF completely. You can determine the value of the shunting resistor from the table below if you know the magnitude of the leakage current and the type of lamp used.

The following formula can be used to estimate shunt value:

Shunt value $R = 900 A / (L - B)$ ohms
(Choose the closest standard value resistor on the lower side.)

Shunt power rating = $1.5 V^2 / R$ watts

Where:

R = Shunt resistor value needed

V = Applied voltage

A = Critical voltage of lamp

B = Critical current of lamp

L = Published leakage current of control circuit in milliamps (or measured leakage current with pilot device in circuit)



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