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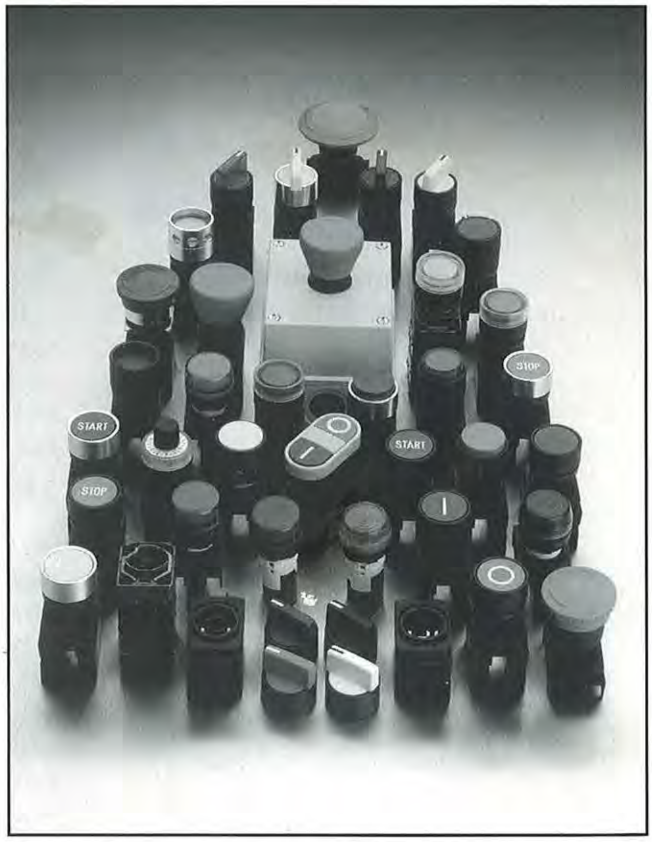
APPLICATION GUIDE TO LAMP SELECTION

The subject of lamp-life and illumination levels as applied to industrial pushbutton and control units is often not fully understood. Because of this there are often unrealistic expectations placed on indicating equipment with a resulting frustration by the end user when the equipment fails to perform up to these expectations.



This issue of Technical News covers the basic types of lamps commonly used in industrial pushbutton and control units. Lamp types include incandescent, neon and light emitting diodes (LEDs). Advantages and disadvantages of each appear in the table below.

IN THIS ISSUE

Type of lamp	Advantages	Disadvantages
Incandescent	Maximum brightness Low initial cost Wide colour options AC or DC power	Low/variable life span Heat generated Fragile filament
LED	Long life Low power consumption Resistance to shock and vibration Cool operation	Moderate brightness Limited colour options Higher cost
Neon	Long life Very low current drain Resistant to shock and vibration AC or DC power cool operation	Limited brightness on AC Output reduced on DC Minimal colour options Tendency to glow with leakage currents Requires at least 70 volts

Application to lamp selection (continued from page 1)

Lamp types

Incandescent lamps

Many users would perhaps misunderstand the published rated life expectancy for incandescent lamps and this is partially due to the way that manufacturers apply the ratings. Manufacturers rarely get the data they use from actual field studies or trials. Instead they test their products under controlled laboratory conditions.

One common method used involves the operation of a number of lamps continuously at their designed voltage and frequency in an environment that is free from shock and vibration until they fail. The life-rating published from such tests therefore represents not the minimum life expectancy from any single lamp but rather the number of hours that it took 50% of a large number of lamps to fail. What they are saying is that 50% of the lamps purchased will probably fail before reaching their rated life.

Some manufacturers may publish life-ratings which are based on a combination of the theoretical evaporation rate of tungsten, actual tests and accelerated life tests in the laboratory.

However, lamps used in real live conditions often face hostile and life-reducing environmental conditions which would not be found in controlled laboratory tests.

Neon lamps

Two types of neon lamps are available, standard and high brightness. Both types operate on the same principle but manufacturers may rate the life span of each differently.

Standard brightness neon lamps emit less and less light as they age. This dimming takes place as the lamps electrodes evaporate and become deposited on the inside surface of the glass envelope. The lamp-life is ended when the accumulated coating on the lamp envelope blocks a high percentage of the lamps original design output.

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

LED lamps

Not well known is that like incandescent and standard neon lamps LEDs also show a gradual decrease in light output as they age. Manufacturers consider that LED lamps have reached the end of their lives when the brightness falls to 50% of the original value.

Factors affecting lamp life

The life span of any given lamp depends to a great extent on the environment. Some of the most common factors affecting lamp-life are as follows:

Shock and vibration

Shock and vibration affect incandescent lamps far more than LED or neon lamps. This is because the delicate filament element grows more sensitive with age. Not only does the material itself become brittle over time, but element evaporation actually reduces the cross sectional area. Therefore, even the most ordinary shock and vibration will lead to early filament fracture.

Obviously care must be taken in handling incandescent lamps so that they are protected from vibration as much as is practical. Careful packaging and installation to minimise shock and vibration are certainly good recommendations but other factors such as slamming an enclosure door can also make a difference.

Low-voltage incandescent lamps perform much better in shock and vibration areas. Lamps rated at say six volts feature relatively short, thick filaments compared to those designed for higher voltages which are made up of many turns of fine wire and therefore offer longer life than higher voltage lamps.

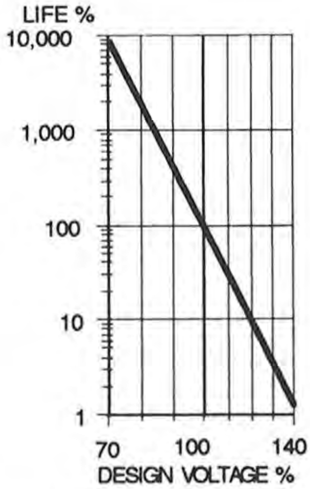
Shock and vibration
(continued from page 2)

Operating voltage

Line-voltage controls the life span of incandescent lamps as well as the quantity of light emitted. The life of such a lamp varies inversely to the applied voltage raised to the 12th power (V12). The light output on the other hand varies directly to the applied voltage raised to the 3.6 power (V3.6). As a result, increasing the line-voltage will shorten the life substantially with only a very small increase in brightness. Referring to **(graph 1)** it can be seen that there is a clear relationship between voltage and lamp life.

The graph illustrates that with an over-voltage of only five percent the life of the lamp will be reduced to 55% of its rated life. Conversely, operating the same lamp with an undervoltage of 5% will result in an actual life span of 175% of its rated value. To offset this, operating the lamp below its rated voltage will result in changes to both the quality and quantity of light output **(graph 2)**. It is therefore clear that in order to achieve maximum life from the lamp that it must be operated at the lowest possible voltage that will still deliver acceptable illumination.

Both neon and LED devices require a current limiting resistor wired in series with the lamp and in many cases this is built into the lamp itself. For LED lamps, often they can be operated on either AC or DC because of the inbuilt bridge rectifier.



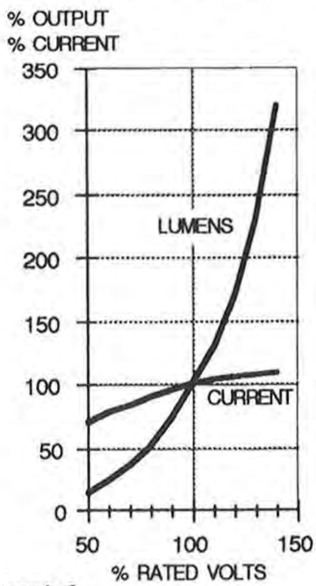
Graph 1

AC versus DC current

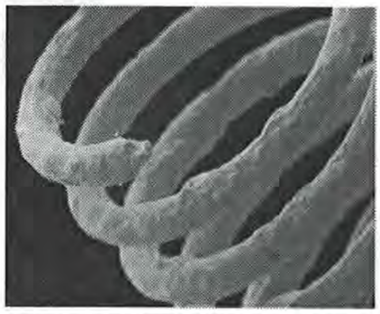
It has been mentioned that the tungsten filament of an incandescent lamp evaporates over time. The result of this is a gradual reduction in the cross sectional area of the filament and even in the absence of significant stress or vibration eventual lamp failure can be expected.

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

- variations in the cross sectional area of the filament
- trace chemical variations which may lead to higher or lower melting points at different points along the filament
- the residual mechanical affects of cold forming and other manufacturing processes.



Graph 2



Filament after 2300 hours of use magnified 822 times (Note evaporation).

AC power results in a more uniform evaporation rate when compared to DC current due to a destructive phenomenon known as DC notching.

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. This obviously results in regional stress and a greater susceptibility to failure. Tests have shown that DC powered lamps may only last 50 % as long as those powered by AC and DC notching represents a major cause of user dissatisfaction with incandescent lamps.

AC versus DC current (continued from page 3)

Research shows that the diameter of the filament has no affect on the size of the notch. Consequently, greater problems are experienced with DC notching at higher voltages because they use thinner filament wires. Therefore each notch has a greater effect. It pays to avoid all DC operation at 110V and even levels as low as 24V can result in relatively low life.

The life of neon lamps remains unchanged whether powered by AC or DC. When powered by DC only one electrode will glow and therefore light output is reduced. When increasing the DC operating voltage to boost output, a rapid decrease in life expectancy occurs.

LEDs conduct current in only one direction so they always operate with DC power. Most LEDs therefore incorporate a rectifying circuit in order to be operated from AC and many can be operated off both AC or DC without trouble. The life expectancy of LEDs on AC or DC should in fact be the same.

Inrush current

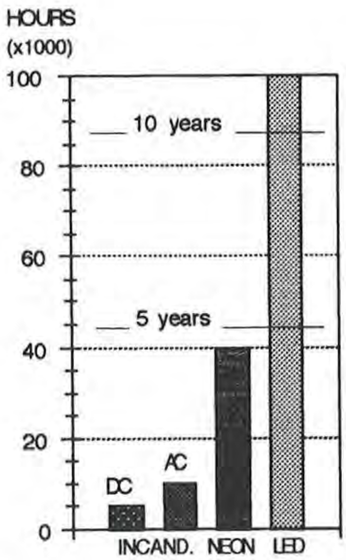
A cold filament offers far less resistance than a hot filament and energising an incandescent lamp results in an inrush current which can be greater than 10 times the normal operating current. This has an effect of reducing the lamp-life due to the thermal shock and could possibly be minimised by providing a preliminary warming current for lamps that are expected to cycle on and off frequently.

Temperature

High operating temperatures decrease the life of any lamp. To minimise the impact of temperature good ventilation should be provided wherever possible.

Characteristics of incandescent lamps

The benefits of incandescent lamps are well recognised. Brightness, variety and low initial cost have made them a popular choice for applications in industrial pushbutton and control units. However, certain characteristics must be considered before selecting them for a given use.



Comparison of lamp life

• Incandescent lamps deliver more light than other types but their output changes over time. That change can take the form of an increase or decrease in output. At higher than rated voltage an incandescent lamp will gradually brighten until failure. Since failures occur without warning, the user has no way of knowing for sure if an unlit lamp signifies an open circuit or a lamp failure. For example, if a lamp is supposed to illuminate, when it is unsafe to energise a piece of equipment, the user will be unaware of the equipment status and might take action that could result in damage or injury.

• Incandescent lamps cost less to buy than other types but those other choices may actually offer better value over a long period of time. For example, the cost of frequent lamp replacement may easily offset the higher initial cost of LEDs.

• A translucent coloured lens placed over an incandescent lamp produces its coloured effect but filters out much of the lamp's output. Translucent lenses transmit only a portion of the light that strikes them.

• When installed in groups such as in control panels, it may seem as if incandescent lamps fail with alarming frequency. Because the lamps are so close together the user may believe that the same element is suffering repeated failures. One economical maintenance practice requires that all lamps in a group are replaced when failure begins and such a policy will save considerable time and money.

Characteristics of incandescent lamps (continued from page 4)

Users of incandescent lamps often express dissatisfaction with short life and the need for frequent replacement. As mentioned earlier, the life expectancy data published by manufacturers does not help because it represents life expectancy under laboratory conditions. Lamps in real world applications face environmental factors that may reduce their actual life by more than 60 %.

The life of incandescent lamps can be maximised by selecting them carefully and by taking the following precautions:

• Use the lowest possible rated voltage to each lamp. For example, transformer type systems using 6V AC lamps work especially well. The thicker filaments used in low-voltage lamps resist shock and vibration far better than thinner filaments used in higher voltage lamps. Therefore, full voltage lamps should only be used in applications with very low duty cycles

• regardless of the lamp's voltage, use the lowest voltage that still delivers acceptable illumination. Avoid operating any lamp over its rated voltage because even a slight change in voltage has a large impact on a lamp's life expectancy

• use AC to power the lamps rather than DC to avoid the notching effect

• avoid placing lamps in areas subject to shock and vibration

• provide ventilation in high temperature environments

• if possible, use a warming current to reduce inrush particularly on applications with frequent on/off cycling.

Characteristics of LEDs

Desirable features of LEDs include long life, resistance to shock and vibration and low power consumption. Where durability and reliability are important, LEDs are the natural choice.

Manufacturers have made significant progress in boosting light output of LEDs in recent times. This has been accomplished by bundling multiple point light sources in clusters inside each lamp assembly. This not only increases light output but provides redundancy as well. Failure of an individual LED chip does not mean failure of the entire lamp, therefore an added measure of safety which may help offset the high cost of LEDs is afforded.

LEDs are available in only a limited range of colours that filters cannot change. Red is the brightest LED colour available followed by amber and green. Although blue LEDs are available, their cost is very high and the quality of light is unacceptable for most uses.

A number of variables complicate the LED selection process. The light output is measured as luminous intensity and most often stated in terms of millicandelas (mcd).

However, output ratings alone are not enough to base a selection. Another variable to consider is the viewing angle. For example, a device with a relatively low mcd rating but a wider viewing angle may be more useful in a certain situation than a device with higher mcd rating that can only be seen from the front. Further, the placement of the chip within the lamp assemblies and the optics of the lens will affect the usefulness of any given LED.

LEDs deliver less and less output over time but rarely fail without visible warning. The gradual decline in output provides an indication when the lamp needs replacement.

Ambient temperature plays an important role in the life of LEDs as a 10°C reduction in temperature may double its life.

Characteristics of neon lamps

Neon lamps offer many advantages because they are rugged and have a resistance to failure from shock vibration or frequency cycling. They offer long life and relatively low cost. In spite of this, neon lamps see only limited use in industrial applications.

One reason for this is the need for at least 70V AC or 90V DC to initiate current flow. Further, neon lamps provide only a limited amount of light within a limited range of colours as most neon lamps produce an orange red glow.

Characteristics of neon lamps
(continued from page 5)

Neon lamps will deliver the longest life and highest light output when operated on AC and operating a neon lamp on DC reduces its life by as much as 50 percent of that same lamp operating at the equivalent RMS AC voltage. Neon lamps are most useful in special applications where low current draw is important. Such use will include that of a blown fuse indicator where it is wired in parallel with a fuse. Lamp current is controlled by a series resistor which is built into the neon lamp assembly.

Conclusion

Proper selection of lamps for the application involve a number of factors. The correct choice depends on specific needs, lamp operating characteristics, environmental factors and overall cost. The choice therefore should strike an acceptable balance among these factors and could involve a compromise between ideal performance and realistic operating considerations.

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