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White Paper:

Self-Ballasted Compact Fluorescent Lamps

Description of Technology

Energy saving lamps… spiral lamps… CFLs… these are all common names for what is technically referred to as a “Self-Ballasted Compact Fluorescent Lamp”. These lamps have been around for a number of years, but in recent time they have been gaining momentum, as the recent focus on energy conservation, utility rebates, energy legislation and improvements in technology have all been making the conditions more favorable for their use. But what makes up a CFL?

A CFL has two basic components: a thin, bent, white glass tube and a plastic enclosure that ends in a standardized socket form.

The thin tube is a smaller version of the fluorescent tubes that are commonly seen in offices, retail stores and even homes. The tube is made of glass and is coated inside with a white powder mix known as the phosphor. The phosphor is what creates the visible light that makes the CFL useful, and the blend of chemicals in the phosphor controls the “shade” of white that is created by the lamp. The phosphor blend also has an influence on the output of the lamp and how well the lamp renders colors. The electrical current runs through the tube and excites the small amount of mercury present and generates a high energy wavelength of light (ultraviolet) that human eyes cannot perceive. This wavelength excites the phosphor powder and converts into a combination of wavelengths that we can see in the proper proportions to generate a light that we perceive as white. The length of the tube is largely (but not completely) linked with amount of light and amount of power generated and used by the CFL, which is why CFL lamps typically get larger in dimension as the power increases. In order to maximize the amount of light that can be given off in a given space, most of the tubes that are currently used in CFLs have either multiple bends in the tubes or are bent in the now familiar helical or spiral shape. This configuration allows for the tube to take up the least amount of volume while maximizing the surface area of the lamp (and maximizing the release of light). This tube alone cannot create light from the socket, it needs a device to control the voltage and limit the current that can flow through the tube. This is where the device in the plastic enclosure comes in.

The plastic enclosure contains the brains of the CFL; either an electromagnetic (rarely) or electronic device that provides the conditions for a CFL to start and run. This is called the ballast, and is why the lamp is called a *self-ballasted* CFL (whereas other fluorescent lamps require ballasts that are separate from the lamp in order to operate). This ballast can contain dozens of components, and typically operates at a high frequency to maximize the light output efficiency. This ballast is specific to the line voltage that the lamp is designed for, typically the standard 120V 60Hz AC power that is present in nearly every light socket in the United States. The ballast is also specific for the wattage and length of the tube that is integrated into the lamp. Since the lamp is integral to the ballast, when either the ballast or the lamp fails, the other will not work and is not replaceable. As a part of this enclosure, a standardized lamp base is utilized as the method of getting line voltage power to the ballast, just as it is the method of getting power to the filament of an incandescent lamp. The most common base is the Medium (E26) base, but there are versions with a Candelabra base (E12) and Intermediate (E14) base styles. All of these are screw-in style bases.

Another type of base that is becoming more popular is a GU-24 base, which is a twist-lock base designed with CFLs in mind, and a base that is not permitted to be used on a non-energy efficient product.

Why use a CFL?

With all of the complexity involved in a compact fluorescent, why would someone go through all of the trouble to make a CFL rather than an incandescent lamp?

The simple answer is energy efficiency, with extended life as an added bonus. Incandescent lamps only convert a small portion of the energy that they use into visible, usable light. Most of their energy is converted into heat, which is only usable in some specific situations. More often, the heat generated by an incandescent lamp simply adds to the climate control load and wastes more energy.

CFL lamps, on a watt-for-watt basis, are typically about four times more efficient than a standard incandescent lamp. This means that instead of using a 60W standard light bulb, a 13W compact fluorescent lamp can be used and achieve roughly the same amount of light. The benefit for the end user is a significant reduction in energy use over the life of the lamp (typically 8 to 10 times that of a standard incandescent lamp), which will far offset any initial price premium of the CFL over the incandescent lamp when used in the right situation. An additional benefit is the wide variety of color temperatures that are available for CFL lamps that are not available (or are difficult to achieve) in an incandescent lamp.

Types of CFL

The most common form of CFL is what is known as a “bare-spiral” or “spiral” lamp. These lamps get their name for the signature spiral of the fluorescent tube. These are the most efficient of the CFL lamps, as there is no cover to trap any heat or reduce the amount of light being projected by the lamp. This also tends to be the least expensive of the types of CFL, as the ballast is relatively simple and there is no extra cost associated with dimming circuitry or high heat components and additional material of the covered lamps. The advantages of this type of lamp are that it will achieve full brightness very quickly, tends to have the longest life, and are the most cost and energy efficient products.

There are compact fluorescent lamps that look very similar to the lamps that they are intended to replace. These are generally referred to as “decorative” or “covered” lamps. This is because a decorative or functional glass cover is placed over the spiral, hiding it from view and improving the aesthetics of the lamp. This is important when the lamp is visible, and the spiral without the cover would look inappropriate or cause uncomfortable glare. These lamps have a few slight changes from a bare (uncovered) spiral lamp. They are built with a paste form of mercury in their tube known as an amalgam, which is necessary to deal with the additional heat present in the tube because the cover does not allow the heat to escape. The side effect is that it takes the lamp longer to get to full brightness. The additional materials and high heat components add significantly to the cost of a CFL when considering a covered CFL lamp. The advantage is that they look like the expected incandescent lamp that they are designed to replace, and can be made as a directional light source (covered reflector type lamps). The disadvantages tend to be shorter life due to increased heat, higher cost due to higher temperature components, and longer time to full brightness.

In order to use a compact fluorescent lamp in a dimming function properly, the lamp has to have a specially designed ballast in order to compensate for the reduction in voltage and to maintain the arc in the fluorescent tube. This additional circuitry involved typically adds significantly to the cost of these lamps as well, and has to be compatible with the type of dimmer being used. Most dimmable CFL lamps are designed to operate on a Triac type dimmer. This is because these have a relatively predictable type of output in wave-form and frequency, and thus are much easier to design dimming ballasts to work on them. Electronic dimmers have a much wider variation in wave-forms and frequencies, and there are few, if any, compact fluorescent lamps that are designed to dim on an electronic dimmer, most CFL lamps will not light at all.

This presents a problem, since most end users do not necessarily know the type of dimmer behind the dimming switch and plate. Even with the proper dimmer type, compatibility issues are not uncommon when dealing with high wattage dimmers (over 600W), and some dimmers do not have the mechanical range or sensitivity to dim the compact fluorescent lamps to the levels that is possible or desired with the lamp.

Lighting Characteristics

All fluorescent lamps make use of a phosphor in order to convert the ultraviolet light that is generated by running current through vaporized mercury into a type of light that is visible and useful to us. The older style phosphors, called *halophosphors*, had issues with the type of light coming out. While they were more efficient than normal light bulbs, the light they put out was “off”. Things didn’t always look right under this type of light. Halophosphors had mediocre color rendering (in the 40s to the 60s, whereas an incandescent light bulb has a color rendering of 100). Many people under the lights felt that it made many objects appear washed out, and these lights were of limited use in situations where seeing the true color of items was important. Newer fluorescent lamps do not use halophosphors, and instead make use of a blend of rare-earth phosphors. These are called *tri-phosphor* lamps because they all make use of at least three phosphors to generate a blend of red-orange, green and blue light. Most modern compact fluorescent lamps use a tri-phosphor to make their light, and have a color rendering above 80, which makes the vast majority of items illuminated by a compact fluorescent appear the way that they should. This is something that needs to be considered when purchasing a compact fluorescent lamp, and is usually on the packaging as “Ra” or “Color Rendering” or “CRI”.

In addition to how well a lamp makes things look the way that they should, there are different colors of white. Most people have noticed that some fluorescent lamps look warm, and even pinkish, while others look very blue. The different shades of white are typically described with a color temperature (described as a 4 digit number with a “K” at the end, such as 2700K), which is the approximation of how hot a filament would have to get in order to generate a light of similar color. For reference, a standard incandescent lamp has a color temperature of around 2600K-2800K, most halogen lamps fall between 2800K-3100K, most commercial fluorescent lamps are “cool white” or around 4100K, and some of the very blue looking lights can be 5000K-6500K.

These color temperatures affect the feel of what is being lit. Higher color temperatures are perceived to be brighter and higher contrast, but can feel cold or harsh, where lower color temperatures are closer to incandescent, and typically have a “warmer” feel to the lighting, but are typically perceived as less bright. The right light needs to be selected for the right scenario.

Operational Considerations

Compact Fluorescent Lamps operate very differently than incandescent lamps, and have some relative weaknesses and limitations in contrast to their strength in energy efficiency and lifetime.

Operating a compact fluorescent lamp releases a chemical within the tube that helps the electricity travel from one end to the other, and is necessary for proper operation of the lamp. This chemical is known as “emitter” and when there is no more emitter to release during startup, the lamp will no longer light. This is important, since much more emitter is released during the initial startup of the lamp than there is when the lamp has started and is operating. This means that the more often a lamp is turned on and off, the shorter the life of the lamp is going to be. As for the amount of time the lamp has been burning, it will have released a proportionally greater amount of emitter. To maximize the life of a CFL, use it in an area that is turned on for extended periods of time.

All fluorescent lamps work most efficiently at a moderate temperature. The ideal temperature for a linear fluorescent tube is 77 degrees Fahrenheit. Below or above this temperature will reduce the efficiency of the product. Compact fluorescents operate in a similar manner and have similar limitations.

Compact fluorescents generally have a minimum starting temperature listed on their packaging and sometimes marked on the ballast itself. This is because the fluorescent tube gets progressively harder to start at lower temperatures. In addition to this, at lower temperatures, the fluorescent lamp takes significantly longer to warm up, and if the temperature is cold enough it is possible that the lamps will never fully warm up to the expected brightness.

In addition to the extreme colds, extreme heat can have a negative effect on compact fluorescent lamps, but for a different reason. The lamps will lose some of their efficiency at higher temperatures, but the real concern is the ballast. Because most CFL lamps make use of electronic ballasts, they are susceptible to a shortened lifetime when used in a high temperature environment. Generally speaking, electrical components are rated for use up-to a certain heat and have a sharp drop off in lifespan when operated beyond that temperature. Compact fluorescent lamps that are properly designed are relatively resistant to the heat that is generated by the operation of the ballast and the fluorescent tube, and can handle heat from most fixtures. Heat buildup can be a problem, however, when a CFL is placed into scenarios where heat cannot be disbursed into the air, or where the ambient temperature is very high.

Along the lines of the ballast, compact fluorescent lamps are essentially electronic products, and should not be used where a significant amount of moisture is present. The ballasts are not typically sealed, because this hinders the flow of heat away from the electrical components contained within. This means that a high humidity environment can allow significant moisture to build up within the electronic ballast, and shorten the lamp's life. Only lamps that are rated for damp locations should be used outdoors, and then the manufacturer's recommendations should be used in determining where they are appropriate.

Motion and photo sensors are becoming more popular among certain types of fixtures, in order to automate controls and save energy. The problem with these technologies is that they typically do not work well with compact fluorescent lamps. Either of these devices will usually draw some small amount of current through the lamp when the lamp is off. This has no effect on an incandescent or halogen lamp, but can wreak havoc with the ballast within a self-ballasted compact fluorescent lamp.

Where to use a CFL

Due to the differences in the way that these lamps create light, there are differences in how the lamp can be effectively used.

CFL lamps are very efficient, and have their longest life when they are on for extended periods of time. This makes them ideal for general illumination in commercial and residential areas where the lights are not turned on and off frequently. Using CFLs where this is the typical pattern of use will return the energy savings the quickest, and will maximize the lifetime (and thus minimize maintenance).

Some commercial applications are recessed lighting, flood-lighting, general illumination and portable fixture lighting (such as table lamps). All of these applications are ones where the lamp will operate for extended periods and will give a better return.

Some residential applications include use in living room, dining room, bedroom and kitchen primary lighting fixtures. In line with the suggested commercial applications, these are applications where the light is likely to be turned on for an extended period of time and will save significant energy, while maximizing their lifespan.

Where not to use a CFL

Due to the limitations of the CFL, there are some applications that will be detrimental to the most effective use of a compact fluorescent lamp, and their use should be avoided in these applications.

Situations where a CFL needs to be turned on and off frequently or needs to be at full brightness instantly are situations where a CFL is inappropriate, particularly when the lamp is a covered lamp (as covered lamps take longer to warm up to full brightness). This is a common problem with dissatisfaction of CFL lamps, and is most often caused because of a lack of education about them. Only turning a compact fluorescent on for several minutes at a time means that the majority of emitter is being used to turn on the lamp, and is significantly reducing the overall life of the lamp. Some examples of this are a bulb in a closet or a bathroom. In either of these situations a lamp is likely to be on only a few minutes at a time, which will reduce the overall life of the lamp. Bathrooms cause an additional problem in that they are typically subject to more moisture than other indoor applications which can also cause the CFL problems.

Compact fluorescent lamps are not typically the ideal scenario when used in security lighting. Many security lights are under eaves, and operate on motion sensors. The idea being that the lamp does not need to be on unless there is something to see, thus only using energy when there is something moving near it. In addition to the problems that can arise from the operation of the sensor itself (drawing energy while the lamp is off), the slow warm up time of covered lamps makes the use of a CFL lamp in a security lighting scenario highly inappropriate. This is compounded because many of these devices are mounted outdoors and subject to cold temperatures, which exacerbate the problem of the lamps not getting to full brightness quickly. Additionally, most security lights are on a timer, and turn off when there has not been motion for a certain amount of time. This creates a scenario where they are operated for relatively short periods of time, reducing life.

Outdoor CFL use presents problems for more than just security lighting. The extremes of temperature that are present outdoors reduce the efficiency and possibly (depending on the scenario) the life of the lamp. Most CFLs are designed to be operated in a “dry environment” only, which means that they need to have minimal moisture present in order to last their longest. This kind of control is difficult in an outdoor environment, and typically only possible when used in a totally enclosed fixture.

Where to Use Caution With a CFL

CFL Lamps Outdoors

An outside environment can be a difficult environment for a compact fluorescent lamp, and it is best to use a lamp that is rated for a damp location when replacing an outdoor incandescent lamp with a CFL. Compact Fluorescent lamps rated for use in a dry environment are not suitable for use outdoors, as the moisture in the air will have a negative effect on the ballast’s electrical components. Even when using a CFL that is rated for use outdoors, there are some considerations to contend with. The major factor to consider is temperature, and what the minimum temperature is expected in the particular location to be used. All CFL lamps have a minimum starting temperature, and as noted previously, all fluorescent lamps are impacted by operating at very low temperatures. Many climates within the United States get too cold for the compact fluorescent lamp to start in the winter. In extreme cold, even if the CFL is rated to start, it will take a very long time for the CFL to get up to full brightness. In extreme cases the CFL may never be able get to full brightness (particularly if the bulb is exposed and the conditions are windy). It is always important to consider the circumstances and environment that the LED will be exposed to when considering an LED lamp for exterior use.

CFLs in Enclosed Fixtures

Enclosed fixtures are one of the most challenging environments for self ballasted compact fluorescent lamps because there is nowhere for heat generated by the lamp and ballast to escape. A standard compact fluorescent lamp that is placed into this environment will typically have a much shorter lifespan than is advertised, as the heat will just build up in the environment and stress the electrical components to the point of failure. Typically the most sensitive part of the lamp will be the capacitors, which help regulate the lamp.

The tricky part is the definition of enclosed fixture. Any fixture where there is no airflow around the CFL is considered a totally enclosed fixture, as it will pool the heat around the ballast. While a lamp in a hazardous location or vapor-proof fixture would be considered a totally enclosed fixture, a recessed can fixture could be considered one too.

Recessed Can Fixtures can be a complicated scenario for the use of a CFL in, and can be considered (depending on the type of recess can) a totally enclosed fixture. There are three classes of recess can, one of them cannot have insulation packed around the fixture, and the other two can. The two types that can have insulation packed up against the fixture are known as I/C (Insulation Contact) Rated and ICAT (Insulation Contact Air Tight) Rated. Either of these types of recess fixture requires the use of a CFL that is rated for *Totally Enclosed Fixtures*. This is still the case if the fixture has an open face, as the heat will pool at the top of the fixture, right where the CFL ballast is. CFL lamps rated for Totally Enclosed Fixtures are made with high temperature components that help maintain the lifespan of the CFL when used in this challenging environment. These CFLs are typically a bare spiral style CFL. Covered CFL lamps are not usually rated for totally enclosed fixtures, since they are already made with higher temperature components to account for the extra heat buildup from the decorative cover over the spiral. Utilizing a CFL that is not rated for totally enclosed fixtures will result in a shorter life for the CFL. The type of recessed can that cannot have any insulation around the can is a non-I/C (not insulation contact) rated can, and will have enough airflow around the CFL ballast that normal CFLs can be operated in this environment. In this scenario, using a covered CFL should pose no problems.

CFL Lamps on Dimmers

Lighting controls are becoming popular, not only in households, but in many commercial and industrial environments for a number of reasons. In some scenarios, the goal is to obtain the proper amount of lighting for a given situation, and in others the goal is to conserve energy whenever possible. In any of these situations, one of the most common devices is a dimmer. A dimmer uses any number of methods to effectively reduce the voltage at which a lamp operates. The problem lies in the fact that a CFL is not a simple incandescent lamp, which is insensitive to dimming method, and is rather a complex electronic device whose purpose is to produce light. Electronics operate on the principle of a relatively known set of operating characteristics. Dimmers do not provide this. Dimming a non-dimmable lamp will result in the lamp not dimming at all, or simply turning off. This will also damage the circuitry of the lamp’s ballast, and result in a very short lamp life. Dimming a dimmable compact fluorescent lamp can get tricky as well, and have some guidelines and requirements:

- The dimmer needs to be a relatively low wattage dimmer (600W capacity and below), and the dimmer should be an electro-mechanical (analog) dimmer. Analog dimmers typically work on a known frequency, and dim in a known manner, which is why most CFL lamps are specified to work on them.
- Most dimmers have a minimum dimming load that should be obtained in order to work properly, usually 40W-60W, but check with the dimmer manufacturer first.
- Dimmable CFLs do not dim in as linear of a manner as incandescent lamps do, so it is usually best not to mix incandescent lamps and dimmable lamps

- Dimmable CFLs should be started at full brightness and allowed to warm up before dimming. Before they are turned off, they should be returned to full brightness for several minutes as well. This allows the lamps to get to a proper, stable state before dimming or turning off, and will extend the life of the lamps.

Properly Disposing of CFL lamps

Compact fluorescent lamps, much like any other type of discharge lamp, will contain some small amount of mercury that is required to produce light. This amount of mercury is much smaller, however, than the amount of mercury that the lamp will typically offset in energy savings from coal burning power plants. Even though mercury contained in fluorescent lamps has been significantly reduced in recent years, it is still the best practice that the lamps be recycled properly, so the mercury can be reclaimed and reused, rather than have the possibility of it working into the environment. For information on recycling programs, please visit www.lamprecycle.org for details. The amount of mercury in these lamps generally presents no danger, but if they are broken, the EPA and Energy Star have published precautions and guidelines for how to safely clean up the lamp on this link.

Summary

Compact fluorescent lamps have improved significantly from the early models that had poor light and were unreliable. They can be used in many places that an ordinary incandescent lamp would be used, and offer good payback in long life and energy savings when used where they are appropriate. Understanding the technology, as well as its limitations, is an important step when selecting where to use a CFL to get the best combination of life, light and energy savings.

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