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LED Lighting for Petro-chemical Industries

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Abstract – *An Industrial petrochemical facilities have predominantly used high-intensity discharge light sources and installation practices unchanged for several decades. Today, new light emitting diode (LED)-based products are being developed, and there appear to be many advantages to this technology; however, caution is advised in its application. LEDs have several unique attributes, and it is critical to understand how they can be used advantageously. Some considerations are dependent on product design but others amount to using LEDs in appropriate situations This paper examines LED lighting technology, standards, safety and available products along with design and application considerations. Moreover, presented are case studies of LED luminaire retrofits in existing facilities. This paper discusses the results of the studies as they relate to safety, environment impacts, capital and operating costs, design implications, and installation improvements.*

Key Words: Color rendering index (CRI), environment, high-intensity discharge (HID), high-pressure sodium (HPS), light emitting diode (LED),lighting, maintenance, safety.

1.INTRODUCTION

LEDs are semiconductor devices that emit light through electroluminescence. This basic fact is the foundation for many of the advantages of LEDs, since it is different from traditional light sources..LED technology is one of the fastest growing electrical/electronics areas of the world. Lighting today represents approximately 20% of the total electricity consumption. As LED technologies gain market share as indicated in Fig. 1, it is predicted that the use of LED technology could reduce lighting energy consumption in the United States by 189 TWh per year, eliminating the output of about 30–1000-MW power plants. This will amount about a 50% reduction in United States lighting energy consumption by the year 2025. The reduction in energy consumption will reduce facility and company environmental footprints and extend the life of our natural resources. More efficient utilization technologies also facilitate harnessing alternate and renewable energy sources as the sole energy sources. Lighting energy costs do not tend to play as significant a role in industry; however, life cycle considerations can be significant.

LED lighting starts with a tiny chip comprised of layers of semiconducting material— the exact material determines the wavelength (color) of radiation that is emitted. At the next level are LED packages, which may contain one or more chips mounted on heat-conducting material and usually enclosed in a lens or encapsulant. The resulting device, can then be used individually or in an array. Finally, LEDs are mounted on a circuit board and incorporated into a lighting fixture, attached to an architectural structure, or made to fit the form factor of a traditional lamp (or as it is colloquially known, a light bulb).

This paper focuses on LED luminaire technology, availability and applications in petrochemical facility environments; however, many of the observations and arguments apply universally. The case studies provide useful empirical data to help make informed decisions when considering retrofitting a facility with LED fixtures or specifying them on a new installation. This paper presents results from the studies including capital cost, energy savings, CO2 reductions, increased safety, reduced maintenance costs, and environmental considerations. This paper also discusses the advantages, disadvantages, and other considerations with currently available LED technology.

Financial considerations—namely, purchase price and operating costs—always figure in the selection of lighting products, but many other aspects also come into play, varying in importance depending on the application. LEDs have several unique attributes, and it is critical to understand how they can be used advantageously. Some considerations are dependent on product design, but others amount to using LEDs in appropriate situations. General-purpose lighting needs white light. LEDs emit light in a very narrow band of wavelengths, emitting light of a color characteristic of the energy band gap of the semiconductor material used to make the LED. To emit white light from LEDs requires either mixing light from red, green, and blue LEDs, or using a phosphor to convert some of the light to other colors. One method uses multiple LED chips, each emitting a different wavelength, in close proximity to generate white light. This allows the intensity of each LED to be adjusted to change the overall color. The second method uses LEDs in conjunction with a phosphor. The CRI (color rendering index) value can range from less than 70 to over 90, and color temperatures in the range of 2700 K up to 7000 K are available.

2. LITERATURE SURVEY

In 1962, the first red LED was developed by Nick Holonyak . In 2012, white LEDs in many configurations were widely available, and these can be more efficient than conventional high-intensity discharge (HID) source. Moreover, indicated is the wide variance in LED luminaire efficacy as compared with HID technologies.

1.1 LED Technologies

LED technologies appear to differ from conventional HID technologies in many areas, including the following.

- The solid-state design of LED luminaires can be more immune to vibration and low temperature extremes, as well as providing "instant on" performance.
- LED luminaire efficiencies are up to 50% better than traditional sources, which reduces energy consumption and power distribution infrastructure requirements. Waste heat is favourable to an extent in colder/wetter climates to prevent moisture ingress or ice formation, whereas it can also be negative in terms of 'baking on' contaminants such as dust or vapours.
- LEDs are inherently small directional sources that, with appropriate optical control, facilitate more efficient and effective lighting designs, in many cases providing a reduced fixture count. This feature can improve lighting designs along with minimizing light pollution, which is becoming a more prevalent environmental concern.
- The driver circuitry can provide wider input voltage tolerances as well as more easily accommodating advanced application techniques such as dimming, occupancy sensors etc, which can further reduce energy consumption.
- Luminaire longevity promises to be significantly longer than HID sources, which can minimize maintenance and life cycle costs. A typical high-pressure sodium (HPS) lamp may last 24000 h, whereas many LED products claim life spans up to 10000 h.
- LED luminaires offer improved lumen maintenance curves (less light output loss over time).
- LED luminaires do not employ mercury, whereas all traditional HID lighting technologies do, which minimizes disposal costs and environmental concerns.

1) LED LUMINAIRES

There are a few significant design considerations in LED luminaire production, which affect efficiency, life expectancy, and quality. Led outdoor area luminaires must compete with other luminaires that are relatively energy-efficient—such as high pressure sodium. The LED chips themselves along with light production and conditioning and driver circuitry within a luminaire all generate heat. Advances are being made in all areas, including adding red led chips in combination with blue, which reduces the need for 'yellowing' phosphor and the associated inefficiency. Heat management both at the chip and the fixture level is critical to led performance and longevity. Driver circuitry for LEDs require a constant current source, and the design of this circuitry in both electrical and thermal aspects presents many practical design challenges.

A. *Industrial Luminaire Availability*

Many new LED products from manufacturers not well known in our industry are becoming available, and it is not clear whether the playing field is level in terms of performance, reliability, and life expectancy. Qualitatively, the application of LED lighting technology in the industrial areas appears to be quite immature and early in the evolutionary cycle. Industrial LED buyers are using 80%-90% less energy than conventional lighting. Energy efficient LED produces a comfortable environment for our customers. Industrial LED buyers produce up to 70% less heat from the light source, therefore making their air conditioning energy efficient as well. For practically all traditional lighting technologies, the end of life is evident: there is no light. And while it is true that traditional fixtures can corrode or color can shift beyond acceptable limits, requiring replacement, and many technologies show some level of light depreciation, for the most part lights-out failure is what people have come to expect. In contrast, LED sources—the core of an LED lighting system—emit light for a long time. Over that time, depending on design, the light output may continuously fade or the color may slowly shift, possibly to the point where low light output or an unacceptably large color change constitutes practical failure. Indeed, during the early stages of the development of LED technology, lumen depreciation appeared to be the principal mechanism that would define the end of life. However, that means that the "end of life" may no longer be clearly evident, a fundamental departure from our traditional understanding.

B. *Reliable Design and Manufacture*

Failures within an SSL luminaire often stem from at least one of four functional aspects of luminaire design and manufacturing: power management, thermal management, optical management, and luminaire assembly integrity. Figure below provides an overview of a contemporary SSL luminaire and the relationships between the various components and materials and design elements.

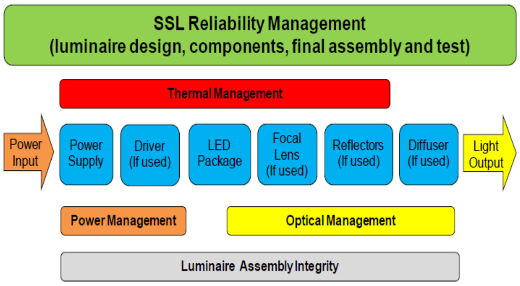

Fig-1:SSL luminaire components and reliability considerations source

Design goals and reliability impacts for each of these four functional aspects are described below.

1)*Power Management* – ensuring the power delivered to the LED package(s) is appropriately sized and filtered.

2)*Thermal Management* – ensuring that heat generated by the LED package(s) and the power system components is removed to minimize LED temperatures so as to maximize LED performance and lifetime

3)*Optical Management* – ensuring that light output from the LED package(s) is correctly and efficiently shaped and directed toward the desired surface.

4)*Assembly Integrity* – ensuring that the overall housing design and assembly process provide for sufficient long-term protection from dust, moisture, vibration, and other adverse environmental effects.

A. *LED Technology Limitations*

Color rendition is not identical to incandescent lamps. A measurement unit called CRI is used to express how the light source's ability to render the eight color sample chips compare to a reference on a scale from 0 to 100.LEDs with CRI below 75 are not recommended for use in indoor lighting.LED efficiency and life span drop at higher temperatures, which limits the power that can be used in lamps that physically replace existing filament and compact fluorescent types. Thermal management of high-power LEDs is a significant factor in design of solid state lighting equipment.LED lamps are sensitive to excessive heat, like most solid state electronic components. LED lamps should be checked for compatibility for use in totally or partially enclosed fixtures before installation since heat build-up could cause lamp failure and/or fire.LED lamps may flicker. The extent of flicker is based on the quality of the DC power supply built into the lamp structure, usually located in the lamp base. Depending on the design of the lamp, the LED lamp may be sensitive to electrical surges. This is generally not an issue with incandescent, but can be an issue with LED and compact fluorescent bulbs. Power circuits that supply LED lamps can be protected from electrical surges through the use of surge protection devices. The long life of LEDs, expected to be about 50 times that of the most common incandescent bulbs and significantly longer than fluorescent types, is advantageous for users but will affect manufacturers as it reduces the market for replacements in the distant future.

The term "efficiency droop" refers to the decrease in luminous efficacy of LEDs as the electric current increases above tens of milliamps (mA). Instead of increasing current levels, luminance is usually increased by combining multiple LEDs in one bulb. Solving the problem of efficiency droop would mean that household LED light bulbs would need fewer LEDs, which would significantly reduce costs.

B. *LEDs for Hazardous Environment*

In fact, LEDs can be used in environments where other technologies fail. They are capable of instant on and instant restrike to –40°C, and they require no warm-up time to be fully bright. LEDs do not produce any harmful UV or IR radiation, which are usually associated with other traditional lighting sources. While LEDs are a directional source of light—directed with optics and lenses, fluorescents need reflectors to direct the light, which loses efficiency as lumens get reduced. LED lighting needs very less maintenance as they have very long life and are well known for high performance. Maintenance in hazardous environments can be dangerous. This challenge can be resolved as LED lights come in sealed units as well which do not require changing for long period of time, and are protected against dust or gas. LED lighting provides 100% light output instantly on being switched on, which is an added advantage for hazardous environments.

LED luminaires for hazardous environments have to be waterproof as these places can be very humid. Keeping these luminaires light weight is another challenge for the designers; so they use plastics which can be used in different chemical environments. Polycarbonate is also used as it is resistant to UV and vibrations of heavy machinery. However, it is not resistant to chemicals, oils or other cleaning fluids. Manufacturers also use copper-free aluminum or stainless-steel to make the housing of the LED lights rugged for harsh environments, and to make them suitable for humid, cold and wet weathers. Sometimes extra coating and resistant proof paints are added to make the housing corrosion proof.

Today, consumers demand small size LED lights, and that's a challenge for the designers. They have to design these LED lights small as well as make them light and resistant-proof to many things. Design also needs to keep other practical concerns in mind. The LED luminaires may also have slots for the dust to fall off. These also keep the luminaire cool.LED lights designed to be used in hazardous environments must comply with standards and rated as per the stringent requirements needed in such areas. It must be checked to ensure that a hotspot or a spark does not lead to fire. Even if an internal ignition occurs, the fixture and the housing should be such that it is not allowed to escape from the fixture or the housing. In LED lights, the hotspot is generally found at the junction, which is put inside the LED assembly. This aspect has to be checked at the manufacturing stage. The manufacturing and testing standards for these LED luminaires are controlled by NEC, IEC and other standards and testing bodies. The industry feels that there should be one accepted standard for temperature rating of LED luminaires.

The relative immaturity of LED technology in the industrial hazardous location market and the rapidly evolving products and standards can make implementation of LED technologies somewhat risky and complex at this point in time. In this uncertain environment, the owner must be ready to purchase fixtures that often cost as much as 2X conventional technologies. The sub optimal optics of many existing industrial LEDs means that a lighting design may require more instead of fewer fixtures. A well-designed and applied LED fixture can result in a lighting design that needs significantly fewer fixtures. While LED luminaires that provide this sort of relative performance must be carefully evaluated and selected, the figure illustrates some of the promise of LED lighting technology. The more directional nature of LED luminaire light output can reduce fixture count with careful lighting design.

3. CASE STUDIES

Three case studies are considered over here. The first case deals with HID luminaire technologies, second deals with retrofits and cost calculations. In third case,a comparison of HID luminaire system replacement with an LED luminaire system along with cost calculations are done.

3.1 Case study 1

In some existing sites, HID technologies predominate, and many luminaire installations do not lend themselves to maintenance as isolation and physical access to the luminaires can be challenging, as illustrated in Fig. 6.To compound matters, many luminaires are energized 24 hours a day and seven days a week for various reasons related to suboptimal design and a low priority on energy consumption. This minimizes lamp life and maximizes maintenance frequencies. Routine lamp replacement can be quite costly. A particular test case was arranged involving a lamp change on the third deck of a vertical tower. The two-man task commenced in the morning and included many of the usual industrial work execution requirements.

Fig-2: Light fixture maintenance at heights

This cost coupled with suboptimal maintainability and a perception that lighting is not as important as direct-production related assets results in fixtures often left in a failed condition for extended periods of time. There is evidence that lower illumination levels and poor-quality illumination negatively affect safety and task execution. Energy efficiency efforts in some facilities are focused on process feedstock and conversion efficiency, chemicals and gas(steam), etc. It has not been common in these facilities for lighting energy costs to figure prominently in management decisions.

3.2 Case study 2

The second case study began with a survey of lighting in an existing process unit conducted over four mornings between 6:00 A.M. and 7:30 A.M. Of the 144 fixtures in the area, 45 were not illuminated due to lamp or ballast failures. Overall, lighting levels were poor at 3 fc. Based on the averages presented in the previous case study in a worst case scenario, costs to replace these 45 lamps/ballasts and bring the facility back up to design conditions would approach $100 k.It was decided to evaluate a retrofit in a circumstance similar to that in case study 1 to evaluate making a stanchion-mounted fixture accessible without the need for ladders, scaffolding, man lifts, or similar access tools. Fig. 9 illustrates the costs for this retrofit. Below chart illustrates the articulating stanchion retrofit hardware kit installed in case study 2.

Fig-3: Retrofit hardware

The change from a fixed mounted stanchion to an articulating variety was accomplished without having the electricians go beyond the railings or requiring any ladders or other elevating means. This case study illustrates that the use of new installation hardware, which makes luminaire access safer and more effective, can be achieved for less than the cost of lamp replacement for stanchion-mounted luminaire installations. When multiplied by the large number of fixtures in many facilities, the savings can be very significant, and these installation methods facilitate maintaining luminaires by providing safe access. Extending the retrofit to include an efficient LED luminaire means that an accessible long-life fixture can be retrofitted for approximately the same cost as changing a conventional HID bulb.

3.3 Case study 3

Case study 3 is another lighting study in a chemical complex originally commissioned in 1984. It was apparent that little attention had been paid to the lighting in recent years based on informal observations. It was also clear that there existed an opportunity to renew the focus on lighting and to make a step change in illuminating the facility. This case study includes consideration of retrofitting LED luminaires including life cycle costs. There were 4568 HPS luminaires and 560 KW of lighting load. An assessment of existing lighting indicated that approximately 25% of luminaires were not operational above grade, which results in a significant reduction in the overall lighting, as well as leaving many dark areas. Approximately 10% of luminaires were not operational at grade, and it is believed that this relatively better performance is based on easier maintenance accessibility. All existing luminaires were qualified as dirty, and the reflectors and guards installed did little to improve light output. Replacing damaged globes, guards, and reflectors was not an option as the products were obsolete and no longer supported by the manufacturer. A review of maintenance records indicated that most lamps were old, resulting in further reductions in light output. Photopic light levels directly below the fixtures ranged from 13 fc to as low as 8 fc.

Foot-candle readings directly below the replacement LED luminaires were as high as 25. The overall return on this project is estimated to be about four years. Following partial execution of this ongoing LED retrofit project, feedback from operating and maintenance technicians has been very positive. Improvements cited include greater ease in reading field tags and instruments during field rounds. An additional benefit is that maintenance and operations technicians are much more aware of the importance and value of lighting in their facility.

Factors /cases	Case study 1	Case study 2	Case study 3	
			HID luminaire(250W)	LED luminaire (150 W)
Environmental impacts	Adverse	Adverse	Adverse	No impact
Safety factor	Very low	Moderate	High	High
Accessibility to luminaires	Difficult	Easy	Easy	Easy
Energy consumption	NA	NA	4.9056 MW hr	2.698 MW hr
Maintenance /Installation cost	$2100	$1170	$784K	$1027K
Annual maintenance cost	$12.6K	$7.02K	$35K	$10K
Total annual savings	NA	$5.58K	NA	$245.76K

Fig -4. Comparison of case studies

3. CONCLUSIONS

LED lighting technology offers many advantages over traditional HID technologies and appears to be the wave of the future. Properly selected and applied LED luminaires should result in reduced lifecycle costs, improved illumination levels and improved safety performance. Industrial LED luminaire development is only a short way into its maturity curve; however, evolution and product development is rapid as evidenced by the proliferation of products and manufacturers not well known in our industry. Applicable standards are also rapidly evolving. Great care should be taken in LED luminaire selection given the wide ranges of performance (variable wattages, photometric outputs, etc.) relative to design applications. Some existing facilities do not pay adequate attention to lighting; however, there are opportunities for improvement with new installation technologies that facilitate safer and more efficient access for maintenance. Innovative techniques can be very beneficial in studying and improving lighting awareness and performance. New LED luminaire technologies offer many concrete financial and environmental improvement opportunities.

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