Cold light – very hot

LED-applications for hazardous areas

by Thorsten Arnhold

Figure 1: High luminous intensity and energy-efficient: LED signal light from R.STAHL

There's life in the old dog yet! This saying seems to be true for the good old incandescent lamps as well. Despite, or better because of the prohibition of sale of 100W light bulbs within the EU which came into effect on 1st September 2009 and which will be gradually extended on all power ratings until 2012, in 2009 e.g. in Germany sales figures of incandescent lamps increased by 50-60% compared to the previous year. There's life in the old dog yet – but not forever. It is foreseeable that in the coming years new illuminants will ensure the lighting requirements in all fields of application.

A red-hot favourite for a leading position in the market for illuminant is LED (Light Emitting Diode): in 2008 already 61 million LED-units have been delivered worldwide . According to the ZVEI –Association of German Electrical Industry- the share of LEDs produced by German manufacturers of illuminants today amounts to 15% of the total sales and further strong growth of the LED-market may be expected. Analysts assume that the world-wide sales increases for the LED-market may amount to ca. 100% per year until 2012.
This remarkable development can be mainly attributed to three reasons:

New developments of high-performance diodes with a continuous increase of light yield.

- With new knowledge in basic research and transfer of this knowledge into the production processes of semiconductor manufacturers, LEDs in different colours (blue, yellow, green, red and others) can be produced today with different colour temperatures. By mixing the colours or by using blue LEDs with photo-luminescent material white light is created.

Improved production processes and production of LEDs in large numbers result in lower production costs. Thus market prices for LEDs fall and make LEDs attractive for a broad range of application in lighting installations. Furthermore, LEDs feature some characteristics which make them especially suitable for use in harsh industrial environment:

- Realization of very compact and efficient lighting solutions, e.g. in places that are difficult to access.
- High vibration resistance makes use of LEDs as illuminant particularly interesting for applications in machine building or in installations with large diesel generators (ships, offshore-installations).

Luminous intensity of an LED can be easily varied by modifying the operating current. Compared to discharge lamps this neither reduces energy efficiency nor service life. That is why light fittings with LEDs are excellently suited for intelligent lighting solutions like e.g. control of luminous intensity of a light fitting with LEDs in relation to the ambient light conditions.

- Service life of LEDs exceeds those of incandescent lamps and fluorescent lamps many times over. Depending on the quality and operating conditions service life between 30,000 and 100,000 hours may be expected. So considerable shortening of the replacement interval for the illuminant and thus reduction of maintenance costs is possible.
- The lower the ambient temperature the higher is the efficiency of LEDs and the longer is their service life. This makes LEDs also especially suitable as illuminants for fields of application with low temperatures over a long period of time. On the other hand, however, it has to be seen that efficiency and service life decrease with rising ambient temperatures.

Due to the properties mentioned above LEDs are also interesting for use in explosion-protected lighting technology. However, the current boom has to be viewed with sobriety and consideration. Technically, due to the above mentioned technological development, the possibility now exists to solve lighting requirements in hazardous areas with LEDs as well. What has to be considered is if the advantages of luminaires with LEDs-, like longer service life and lower maintenance costs, justify higher purchase costs.

A simple example is meant to illustrate this fact: when replacing a common single lamp 36W linear light fitting by an LED-solution that is equal in regard to lighting, the one fluorescent lamp, that has an purchase price less than 1 Euro if large quantities are ordered, has to be replaced by ca. 30 LEDs, each of which currently still costs ca. 1 Euro. When the wiring expense is added, the complete LED-illuminant will cost ca. 40 Euro. Good fluorescent lamps nowadays have a service life of 30,000 to 60,000 hours. Even if the significantly longer service life of the LEDs is taken into account it has to be said that replacing of common illuminants currently only is economically advantageous in exceptional cases, e.g. if the installation site of the lamps is extremely difficult to access and thus exchange of illuminants would be highly expensive.

This statement, however, only describes a snapshot of the situation on the LED market. At the moment, due to technical progress and the associated reduction of manufacturing costs, this market develops so fast that already in the near future a large-scale replacement of the conventional lighting technology could be possible. Before presenting some interesting lighting solutions for potentially explosive atmosphere using LED-technology, the following paragraph tries to give some information on the state-of-the-art of LED-technology, giving special attention to explosion protection.

Technical developments and restrictions of LED technology

Light Emitting Diodes have been used in industry for many years now. A compact overview of these developments and of the physical basics is given in article ›White light‹ from LEDs‹ in Ex-Magazine 2004. Especially vibration resistance and long service life resulted in large-scale use of LEDs for signalling. If a common incandescent lamp has to be replaced every 1,000 hours on average, service life of LEDs of ca. 50,000 hours and more may be anticipated. So in hazardous areas LED-technology has been applied at an early stage: since the 1970s R. STAHL offers patented explosion-protected LED indicator light (figure 2).

However, in the beginning the relatively poor light output and the fact that LEDs could only be produced in red, green and yellow limited the possibilities for application. Only around the turn of the millennium came the breakthrough. To begin with, by using material combination InGaN on a sapphire substrate, an LED has been developed in Japan that could emit a bright blue light. Then it became possible to produce efficient white LEDs by combining a blue LED with a luminescent material that absorbs the blue light so that

Figure 2: Patent explosion protected indicator light with LEDs built in a control unit

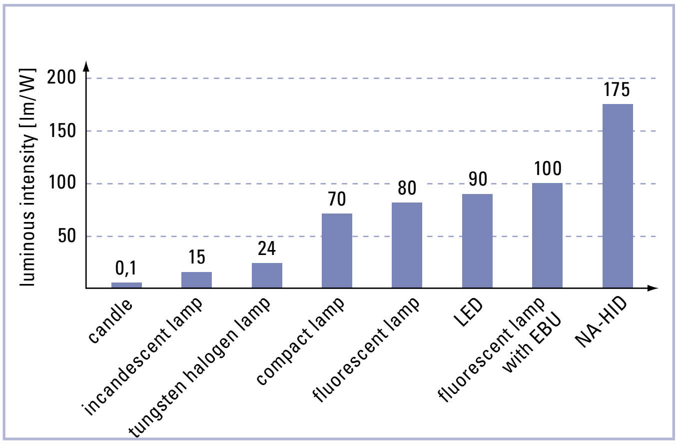

Figure 3: Luminous intensity of different types of lamps

a wider spectrum in the visible range is emitted. Together with the continuous increase of efficiency these developments led to LEDs capturing fields of application that up to then have been reserved to conventional illuminants like filament lamps or gas-discharge lamps.

An important characteristic of an illuminant is the light yield. It indicates how much of the electric power fed to a light fitting is transformed into a luminous flux perceptible to the human eye. Figure 3 gives a survey on the light yield of different illuminants.

Many of the LEDs available on the market today have a luminous efficiency between 40 and 90 lumen / Watt. This is in parts slightly less than fluorescent lamps have (50-100 lumen / Watt), but significantly more than incandescent lamps or tungsten halogen lamps. The value of the leader, the high-pressure sodium vapour discharge lamp reaching 175 lumen / Watt, the most efficient white LEDs, having 160 lumen / Watt, currently do not yet reach, but it is foreseeable that this threshold will be crossed in the near future as well. Currently LEDs with such a high luminous efficiency are extremely expensive as they can only be produced with complex selection procedures.

Central problem when using high-performance LEDs is a certain temperature influence. The temperature problems this causes cannot be attributed to the generation of light itself – LEDs generate light by electroluminescence and can thus only emit ›cold‹ monochromatic light.

But as electrical power loss is not transformed by radiation of light, as with the incandescent lamp, the complete power loss has to be dissipated via the surface of the chip, which is only a few mm² in size. If this does not happen, very high temperatures may build up at the semiconductor material of the LED which leads to a shortening of service life or to destruction of the LED. Avoiding of hot spots has a special importance, especially in regard to explosion protection, besides their impairment of function and service life of the LED.

Under normal temperature conditions, as given in the data sheets of the manufacturers, LEDs that are operated with low currents achieve a service life of more than 100,000 hours. Specification of service life in the manufacturer's documents usually gives information on the part of the complete number of test LEDs that are still functioning. So the information: › B 50 at 100,000 hours‹ means that after an operating time of 100,000 hours under specified conditions 50% of the examined diodes still function or, the other way round, that after this time half of the LEDs do not function any more.

Applications in explosion protected electrical equipment

As already mentioned above, almost all known lighting requirements for industrial installations, including hazardous areas, can in the meantime also be met by using LEDs. The only question is if the overall achievable cost-performance ratio will be accepted by the customers. Many of the currently offered LED-based solutions are, in regard to prices, comparable to common explosion-protected light fittings, but with a closer look it is noticeable that the lighting engineering properties are not always satisfying. Or there are designs that are comparable to conventional products in regard to technology but are much more expensive. Below, some explosion-protected luminaires using LED technology will be presented and the advantages of their application.

Types of luminaires which clearly show the advantages of the new technology and for which LEDs as illuminant have already been established are hand lamps and torches. So far only incandescent lamps with a short service life and poor luminous efficiency have been available for these lamps, so that here LEDs have been able to show their superiority already for a few years. In most cases the high internal resistance of the batteries is enough to ensure a relatively constant supply current. The narrow angle of radiation, which is typical for LEDs, is no problem with this type of lamps. Figure 4 shows an explosion protected LED-torch with the marking II 2G Ex ib IIC T4 or II 2D Ex ib D21 T81°C IP 68 by R. STAHL.

Figure 4: Explosion protected LED- torch light

Another product which features the advantages of LEDs is the LED-cluster luminaire type 6590 (figure 5). Special feature of this luminaire , approved for Zone 2, is the rapid and flexible fitting to a special ribbon cable. Contacting is done by piercing technology when the luminaire enclosure closes with a snap, without further work steps. As the insulation material of the cable possesses self-healing properties, later modification of the assembly position can be easily accomplished. Typical fields of application for this LED- luminaire are marking of escape routes and lighting of banisters, hand rails, stairs and switch cabinets. Type of protection is ›non-sparking‹ Ex nA.

Instant start of LEDs and high number of switching rate that do not impair service life is more and more often also used for applications in signalling. Figure 6 shows a flameproof signalling lamp type 6162 that may be used in Zones 1, 2, 21 and 22. By using LED technology an energy-saving solution with a very good signalling effect is achieved. With low current consumption self-heating of the lamp is low, so that temperature class T6 or the permissible maximum temperature of 80°C is kept and thus a wide range of application in dust explosion protection is possible as well. The different functions of the signalling lamp are set via a terminal with the respective software. In the example the use of continuous light or rotating light (beacon light) is possible. For application as beacon light no mechanical moving parts are used any more in the lamp so that service life increases significantly (see Product-News page 61).

Further fields of application are flashlights or flashing lights using LEDs. Here a decisive advantage in comparison to signalling lamps with common halogen or xenon lamps also is the very long service life of the LED illuminant. In the meantime there are alternative products based on LED technology for linear light fittings as well. Figure 7 shows a tubular LED linear light fitting. The transparent plastic tube is a closed flameproof enclosure in type of protection ›d‹. With several LEDs a luminous intensity is achieved which approximately corresponds to a 14 W fluorescent lamp. Typical fields of application of such a light fitting are, e.g., machine illumination, illumination of escape routes and information signs as well as lighting of areas that are difficult to access. Because of a robust design

Figure 5:
Led-cluster luminaire type 6590

Figure 6:
Signal lamp type 6162 in type of protection flameproof enclosures ›d‹

and the use of high-quality LEDs it can be said that these light fittings are all but maintenance free.

The time-honoured pendant luminaire can be modernized with LED-technology as well. Figure 8 shows a flameproof enclosed pendant luminaire with a high-performance LED-element. The arrangement and number of LEDs is determined by the lighting requirement and the specified luminous intensity distribution. Contrary to high-pressure discharge lamps and incandescent lamps LEDs have a →

narrower radiation angle. If a radiation of 360° is required either several LED-modules have to be arranged in the pendant luminaire in such a way that they emit light in different directions or special optics have to be used distributing the light accordingly. Additional costs for such solutions are justified for special applications, e.g. if a long service life is required, application in temperatures below -30°C or if instant re-start of the lamp after a power failure is required.

Figure 7:
Tubular linear light fitting with LEDs

Figure 8:
Flameproof pendant luminaire with high performance LED insert

Future prospects

LEDs undoubtedly are the illuminant which in future will fulfil the majority of lighting requirements. The rapid development of LED-technology during the past decade is far from over. So product properties will surely be further improved in the years to come. The values that may be achieved have already been mentioned above. Further improvement of production technologies, continuously increasing production rates and the growing competition on the world markets will make sure that costs and thus market prices will continue to fall.

Another interesting point is what improvements can be made on the field of OLED-technology. Compared to the hitherto known LEDs, organically based LEDs emit light on a large area and thus get close to natural light distribution. Currently, this technology is not technically mature in regard to service life and luminous efficiency and for that reason it is only used for special applications.

Development and production of 200W and 400W floodlights for Zone 1 can already be realized today, but the question arises if the customers are willing to pay the higher price for LED-luminaires.

Despite the optimism in regard to application of LEDs as an illuminant one should not fail to notice that replacement of lighting installations containing older light sources can only happen gradually over a longer period of time. This is suggested by long-standing habits, a mass use of the previous technology in already existing installations and deficiencies in regard to information on the new technology among the staff and in the documents of planning, installation and operating companies.